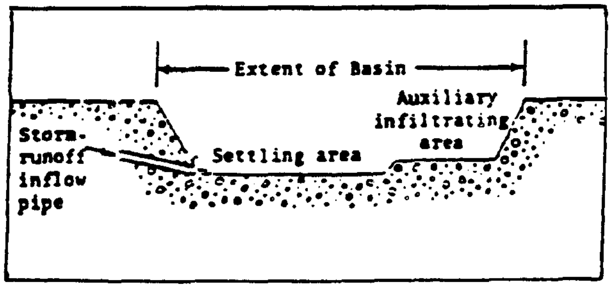
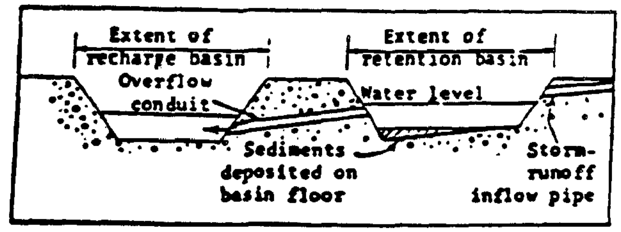
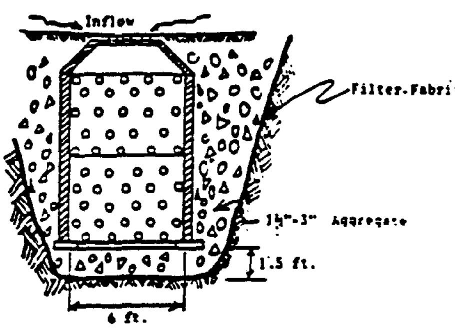
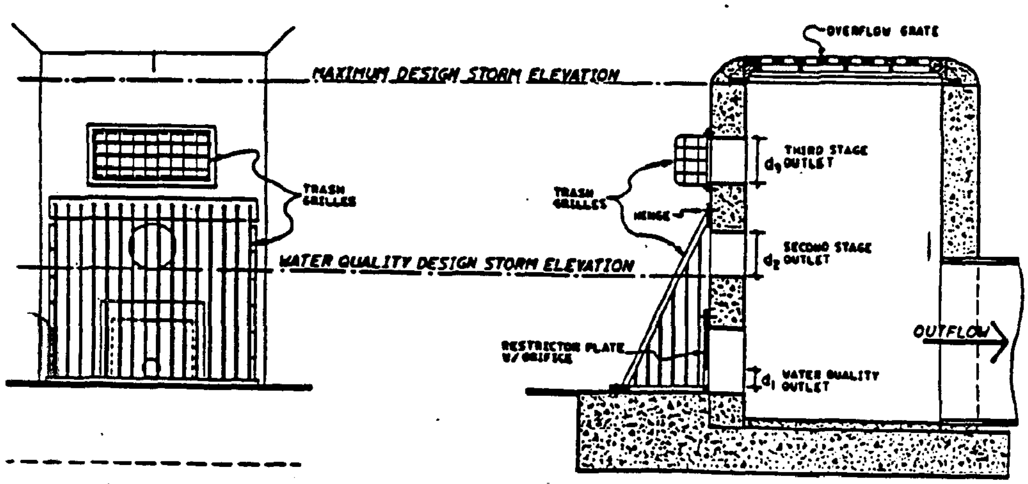
A Guide to Stormwater Management Practices In New Jersey









April 1986

lew Jersey Department Of Environmental Protection/Division of Water Resources

A GUIDE TO

STORMWATER MANAGEMENT

PRACTICES IN NEW JERSEY

Division of Water Resources
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INTRODUCTION

Under provisions of the New Jersey Stormwater Management Act (PL 1981, c. 82) and its implementing regulations, (N.J.A.C. 7:8 - 1.1 et. seq.), procedures and standards for stormwater management have been established, for implementation by counties and municipalities. These regulations are attached as Appendix A. The mandatory requirement for these local agencies to control stormwater management is contingent upon the availability of a grant to cover 90 percent of the necessary planning costs. The policy of the Department is to request such funding only to cover the higher priority situations, where economic growth is rapid enough and the consequences of flooding downstream serious enough to warrant early imposition of storm water management controls. Such priorities have been made known to agencies concerned. In general, all rapidly developing areas, except those on barrier islands, need such controls.

The Division of Water Resources is aware that there is a great diversion in stormwater management controls already in effect. The greater part of the structures built so far consists of single purpose detention basins; and many consulting engineers and municipal engineers are entirely familiar with the technology involved. Moreover, many texts and reference books cover the subject. However, conditions in urbanizing areas of New Jersey require general use of dual purpose detention basins, in the interest of water quality; and the use of infiltration basins and other volume controls is also of increasing interest. Therefore, this report provides general guidelines and some technical guidance for use of such structures, with reference to publications where further details may be found.

These standards and specifications are provided as design guides to engineers familiar with the technical aspects of stormwater hydrology, hydraulics and soils engineering. Engineers are not limited to utilizing only these techniques in the preparation of storm water management control plans. The use of other techniques such as roof top or parking lot storage, underground storage etc. are suitable alternatives when properly used. Additionally, the design methods presented are not the only methods that can be used to design the techniques discussed.

Stormwater management control techniques are sometimes defined as either rate or volume controls. Rate controls are primarily used to reduce the peak rates of runoff, and thereby to provide local control of runoff problems. Volume controls are used to actually reduce the volume of runoff and are effective for both local and regional runoff control. The most effective management techniques (such as those of New Jersey), combine rate and volume controls. The New Jersey State Stormwater Management Regulations require rate control of a range of design storms and volume control of a water quality design storm. The rate controls are based on reproducing predevelopment peak rates, the water quality controls require the volume of runoff be retarded so as to reduce the transport of pollutants as well as reducing flooding downstream. The water quality requirements can be satisfied by providing prolonged retention in a rate control facility (i.e. detention basin) or by the production of zero runoff through a volume control (i.e. infiltration techniques). The combination of these requirements provide local and regional flood control as well as enhanced water quality.

The designer and the planner should review the overall objectives of the stormwater management plan or policy to insure that the control techniques chosen provide the desired level of control.

With only a few exceptions, existing local stormwater management controls in New Jersey, exemplify a site-by-site approach. It has been known for some time, as stated in the regulations, that much better results can be obtained by planning systems which are adopted to an entire drainage basin. With the cooperation of the U.S. Soil Conservation Service and Hunterdon County, a demonstration planning project has been carried out, the results of which are summarized in areport, "Regional Stormwater Management Planning, South Branch Rockaway Creek", March 1986, which is being distributed separately.

In preparation of the present report, contributions of the work group and participating agencies for the regional study provided major input, particularly those of the U.S. Soil Conservation Service. The major portion of information presented herein on infiltration techniques was taken from "Standards and Specifications for Infiltration Practices" prepared by the Maryland Department of Natural Resources, Water Resources Administration Stormwater Management Division. The New Jersey Division of Water Resources appreciates the assistance supplied by the Maryland Division of Natural Resources in providing this information on the design of infiltration techniques for storm water control.

Although an effort has been made to be consistent with the policies of all participating agencies, the final working of this document is that of the Division of Water Resources, Department of Environmental Protection.

CHAPTER 1

General Planning Guidance

The planning of stormwater management structures under the regulations is governed by performance standards. Provided certain criteria are met, the State policy allows considerable latitude in accomplishing the desired objectives.

However, such flexibility is not without its limits; and there are some practices which, while nominally effective, have inherent limitations greatly limiting their ability. Also, there are some secondary effects, such as environmental aspects, which may control. Any guidance in this document is subject to various other legitimate objectives, each important in its own field, including such items as groundwater pollution, insect vectors, endangered species and wetlands.

Since the basic purpose of stormwater management is to compensate for the added storm runoff and the runoff pollution caused by development, some form of storage or detention of stormwater runoff is the characteristic feature of the program. The term detention (or rate control) usually refers to the holding of runoff for periods not over a few hours, while retention (or volume control) refers to methods of infiltrating runoff into the ground or otherwise holding it back for a longer period.

Most stormwater management ordinances in the past established criteria only for peak flows, on a site-by-site basis. For example, the peak flow from a 100 year storm after development should not exceed that from the same storm prior to development. When faced with such criteria, competent engineers, considerate of costs for their clients, naturally designed single purpose detention basins with a single outlet. The demonstration project analysis (previously referred to) clearly indicates the inherent deficiency in such designs - the effects of site-by-site rate controls even a few miles downstream are completely ineffective. Recognizing this relationship, the state stormwater management regulations require the prolonged storage of a small design storm which, besides favoring flood control downstream, reduces the pollution from urban runoff. The state standard is a minimum standard for flood control and water quality of "dual purpose" basins. Single purpose detention basins are only acceptable when combined with some other measures which reduce the runoff pollution, such as grassed swales.

Infiltration basins have been widely used in areas with porous soils, and under appropriate circumstances they may be fully effective for water quality retention as well as rate control of major storms. Volume controls, such as infiltration techniques, are usually limited to use with small runoff volumes, therefore they will be most effective when applied to small design storms. Attempts to design such controls for design storms above the 2-year event are usually impractical. As indicated in detailed guidance below, infiltration basins must be carefully analyzed for permability of soil, seasonal high water table, and necessity for maintenance of deposited sediments, in order to prevent clogging by colloidal particles. Even more important, it is absolutely essential that possible groundwater contamination be taken into account. Urban runoff usually contains considerable concentrations of hydrocarbons, and often of nitrates, which may unacceptably pollute groundwater. Not only infiltration basins, but also systems of infiltration trenches and dry wells, should be subjected to an analysis of the anticipated pollutants and their effect upon groundwater before such systems are approved. Vegetated swales are less likely to cause problems of this sort.

Although infiltration basins can be cleaned out to remove accumulated sediments, this is not the case for infiltration trenches and dry wells. Urban runoff generally contains considerable sediment. Such structures are only permanently usable for stormwater management when designed for runoff from roofs or grassed areas not likely to contain suspended sediment. If, due to space limitations, there is no other alternative, provision should be made for additional capacity capable of holding an estimated 20 years of suspended sediment load.

Planners should carefully consider the lessons to be learned from the report on basin wide demonstration project. Although the results cannot be applied automatically elsewhere, they indicate some practical points which may reduce the scope and cost of engineering studies required to find an optimum solution. In particular, the combination of at-site measures to control small storms combined with regional basins to control the larger storms, is apt to be widely useful. It is almost certain to be more satisfactory and more economical than a simple site-by-site approach imposed uniformly by an ordinance.

Of course, the first stage of control for a municipality must be an ordinance, which can then be replaced by specific basins plans as fast as they can be developed. A model ordinance suitable for Phase I planning is attached as Appendix B.

CHAPTER 2

2.1 DUAL PURPOSE DETENTION BASIN (DB) – as opposed to single purpose [illegible]

Description

A dual purpose detention basin is a temporary water impoundment made by constructing a dam or an embankment or by excavating a pit or a dugout in undisturbed soil. The purpose of the basin is twofold; to promote the settlement of runoff pollutants by retaining the first flush for a prolonged period and to temporarily store the surface runoff from a selected design storm or a series of design storms by restricting outflows to a predetermined rate.

Applicability

A dual purpose detention basin will be generally used where a significant volume of runoff is to be controlled. Detention basins are the most popular control technique for managing storm water runoff. The detention basin will typically be utilized for drainage areas from one acre up to several hundred acres. Detention basins may be combined with an infiltration basin (IB) or a wet pond by raising the outlet pipe to allow predetermined volume of stored runoff to infiltrate, or to be retained. Where possible the infiltrated volume should be equal to the runoff from the water quality design storm.

Planning Considerations

On small sites with large percentages of impervious cover, detention basins can occupy significant portions of the site. In cases where the conventional basin design results in unacceptable revisions to the plan layout, other control practices should be investigated.

A typical dual purpose detention basin will range from three to twelve feet in depth. Depth is often limited by groundwater conditions or by the need for positive drainage from excavated basins. The depths are often limited by the need to minimize the in inundation area or "take line" associated with the top of the embankment. A typical basin will be constructed with a combination of excavated and diked storage.

The nature of the dual purpose detention basin concept, the collection of site runoff, will usually require the facility to be located at the lowest elevation of the contributory drainage area. On many sites, this means locating the detention basin along a stream or within a flood hazard area. When so located, the outlet structure can be influenced by backwater from the stream or flood hazard area and the intended effect of the detention basin partly or entirely nullified. The New Jersey State Storm Water Management Regulations contains criteria for such situations.

Design Criteria

The following design criteria should be considered as minimum requirements. Where applicable or desirable, additional criteria may be added to or required in place of these minimum criteria, as long as such additions or replacements equals or exceeds the degree of water quality and flood control achieved by these minimum requirements.

Design Storms

All hydrologic and hydraulic calculations shall be based on the design storm criteria provided in the New Jersey Storm Water Management (SWM) Regulations (NJAC 7:8). These design storms shall be defined as either a 24-hour SCS Type III storm or as the estimated maximum rainfall for the estimated time of concentration when using the Rational Method. The regulations specify the 2-year, 10-year and 100-year storms as flood control design storms and the 1-year storm or a one and one quarter inch two hour rainfall as the water quality design storm.

Release Rates

The release rates for dual purpose detention basins shall be determined in accordance with the water quality, flood and erosion control requirements of the New Jersey SWM regulations (NJAC 7:8). The water quality design storm must be retained and released such that no more than ninety percent of the runoff is evacuated in less than 18 hours for residential developments and no less than 36 hours for all non-residential projects. For flood and erosion control, the regulations require the runoff from the 2-year, 10-year, and 100-year storms be controlled such that peak flows from a site shall not increase as a result of development. Also, when computing runoff peaks, all lands in the site shall be assumed, prior to development, to be in good hydrologic condition Specifically, when using Table 1.2 of Technical Release-55 predeveloped lands will be assumed to be in good condition if the lands are pastures, lawns, or parks; with good cover, if wooded; or with conservation treatment if cultivated regardless of the conditions existing at the time of computation.

The discharge rates and volume of the discharge from detention basins can be fairly large, especially in relation to the capacity of the receiving streams or swales. Concerned efforts should be made to set release rates from the basins to levels that will reduce downstream flooding and erosion potential. Release rates are often tied to "predeveloped" rates of runoff. Recognizing the fact that these predeveloped rates may be damaging, many communities have used release rates based on other than the existing condition rate of runoff. The use of a percentage reduction, such as 50% of the predeveloped rate or predeveloped condition of the site be considered in a "natural" state, such as meadow, are two of the more popular methods used to reduce basin outflows. The use of these rate reductions schemes can often be justified by the need to reduce downstream impacts or by the fact that detention basins do not reduce the increased volume of runoff caused by the development and the rate control must be adjusted to safely control the increased volume.

Alternatively, the release rates may be tailored to a regional or a state approved Phase II SWM plan. In such cases, downstream impacts must be evaluated in detail to insure that minimum requirements equivalent to those of the New Jersey SWM regulations are equalled or exceeded.

Water Table and Ground Water Conditions

At the location of the proposed dual purpose detention basin, the depth to the seasonal high water table (SHWT) should be identified. If the basin is to intercept the ground water table, the effects of seepage on the facility should be investigated. Basins that do intercept the SHWT may have unstable side slopes and may create maintenance problems due to the seepage especially where mowing is required.

Runoff Filtering

In order to reduce maintenance costs, inflows to dual purpose detention basins may be filtered prior to entering the facility. Filtering can be accomplished through the use vegetated swales or filter strips. Removal of grease, oil, organics and sediments from the runoff will serve to increase the efficiency of the detention basin as a water quality enhancement technique, and will also reduce maintenance problems. Heavy sediment loads should not be allowed to enter the detention basin unless adequate provisions are made to remove accumulated sediment. Known pollutants loads such as floating petroleum should not be routed into a detention basin, but be controlled at source.

Principal Spillway Systems

The principal spillway systems for a detention basin should be designed to accommodate the required design storms. The spillway structure should be located such that it is readily accessible for maintenance. Easement or right-of-way access should be provided.

From a structural standpoint the outlet structure should be designed to withstand all anticipated pressures or loadings. If heavy equipment will be required for maintenance, the outlet structures should be designed accordingly. Provide vehicle access so that debris can be removed from a spillway when in operation.

Dual purpose detention basins designed according to the New Jersey SWM regulations will usually involve multi-stage outlet systems. The lowest outlet will be designed to achieved prolonged retention requirements for water quality enhancement. The invert of the first flood control outlet (2-year control) will then correspond to the maximum water surface elevation produced by the water quality design storm. The principal spillway system should be sufficient to pass all the required design storms.

Outlets from detention basins shall be designed to function as designed without manual, electrical or mechanical controls.

Anti-seep or cutoff collars should be used to avoid potential piping along the outlet conduits. The use of good quality fill and sufficient compaction around the conduit and collars is essential. All conduit joints should be water tight and the number of conduits through the embankment should be minimized. Where thin walled conduits are used through the embankment, a protective exterior encasement should be used. The design of the conduit should attempt to minimize internal water pressure.

Emergency Outlets

All drainage facilities should be equipped with emergency overflow systems to ensure safe passage of flows larger than those from the design storms. Detention basins should be designed to include an nonerosive emergency spillway. The design of the spillway will depend on the size and location of the basin. At a minimum the emergency spillway should be designed to pass the maximum design storm with sufficient freeboard assuming no flow through principal spillway. This would apply to all detention basins not classified as a dam. All dams, as defined by the New Jersey Safe Dam Act and the New Jersey Dam Safety Standards NJAC 7:20-1.1, must have emergency spillways designed in accordance with the Dam Safety Regulations.

Vegetated emergency spillways should have side slopes not exceeding 1 vertical to 4 horizontal. Velocities in vegetated spillways should not exceed the permissible non erosive velocities listed in Table 3-3 and the criteria contained in Hydraulic Engineering Circular No. 15 - Design of Stable Channels with Flexible Linings or Standards for Soil Erosion and Sediment Control in New Jersey.

Dams and Embankments

All detention basins involving the construction of an embankment that raises the water level five feet or more above the usual, mean, low water height when measured along the downstream toe-of-dam to the emergency spillway crest is classified as a dam and must be designed, constructed and maintained in accordance with the N.J. Dam Safety Standards (NJAC 7:20). All other detention basins with embankments shall be designed in accordance with the following criteria.

Top Width: The minimum top width of the embankment shall be 10 feet.

Side Slopes: The side slopes of the settled embankment should not be less than 4 horizontal to 1 vertical.

Freeboard: The minimum elevation to the top of the settled embankment shall be one foot above the water surface in the detention basin with the emergency spillway at the maximum design flow or a minimum of two feet above the crest of the emergency spillway, which ever is higher.

Settlement: The design height of the basin embankment should be increased by ten percent where hauling equipment is used for compaction and five percent where compaction equipment is used. All earth fill shall be free from brush, roots and other organic material subject to decomposition. The fill material in all earth dams and embankments should be compacted to at least 95% of the maximum density obtained from compaction tests performed by the appropriate method in ASTM D698.

Vegetation

The embankment, emergency spillway, spoil and borrow areas, and other disturbed areas shall be stabilized and planted in accordance with the appropriate vegetative measure standards in Standards for Soil Erosion and Sediment Control in New Jersey.

Water tolerant species of vegetative cover for pond surfaces should be used to maintain high infiltration rates and aid decomposition of settled particulates. Forage and fodder crops, such as canary grass, fescue, perennial rye, orchard grass, and bermuda grass can be used to successfully treat large amounts of runoff, and are tolerant of variations in water quality.

Water Quality

A unique aspect of the New Jersey storm water management regulations is the requirement for water quality control. While water quality enhancement may be achieved through a variety of SWM techniques, detention basins are the most widely used in New Jersey. Dual purpose detention basins designed according to the standards of the NJSWM regulations provide significant reductions in runoff pollutant loadings. Prolonged retention of the runoff from the water quality design storm promotes the settlement of particulates. Sorbed to the surfaces of these particulates are a variety of runoff bourne pollutants; of particular concern are petroleum based organics, heavy metals, and undissolved phosphates.

Construction Specifications

The construction of all detention basins should comply with the Standards for Soil Erosion and Sediment Control in New Jersey and the additional criteria provided below.

Schedule

The sequence of various phases of basin construction should be coordinated with the overall project construction schedule and the approved soil erosion and sediment control plan. Scheduling rough excavation of the basin with the rough grading phase of a project permits the use of the excavated material as fill in earth work areas. The partially excavated basin could serve as a sedimentation basin during construction. However, basins near final stages of completion should not be used for the disposal of runoff from exposed surfaces, as this will result in large sediment loads being deposited in the basin. Final grading, seeding and cleaning of accumulated sediment in the basin and the outlet structure should not occur until all disturbed areas have been permanently stabilized.

Specifications for basin construction should state: (1) whether the basin will be used for sediment control, (2) at what point the basin will be converted to a detention basin and (3) how the transition will be accomplished. The last statement should include a list of activities to be performed such as removal of temporary riser pipes, clearing of sediment, final seeding, etc.

Maintenance

Schedule

All drainage systems must be routinely inspected to ensure proper operation s. Inspections should be scheduled for all facilities after major storms for routine maintenance and at least bi-annually for structural inspections.

Sediment and Debris Accumulation

All detention basins will accumulate sediment and debris. Basin designs should include storage for at least on years accumulation of sediment to ensure the stage-storage-discharge characteristics of the facility are not adversely affected by routine sedimentation.

Debris and most sediment will accumulate around the outlet for the basin. To protect the outlet from clogging, adequate trash racks and proper outlet designs are necessary. Trash racks should be arranged in series to provide two stage protection. Openings in these screens should be small enough to restrict debris yet large enough to avoid excessive clogging and interference with the hydraulic function of the outlet. Inclined trash racks are preferred as debris will tend to ride up with the water level. All protective screen/racks must be hinged to facilitate the removal of accumulate debris and sediment.

To prevent the re-suspension of deposits of sediment in the basin, energy dissipators should be employed at all inflow points. Reduced inflow velocities will also help promote sedimentation.

The New Jersey Department of Environmental Protection and Ocean County are currently conducting an investigative study on the maintenance of storm water management facilities. A major goal of the study is the development of a maintenance manual that will include information of the financial, legal and engineering aspects of long term maintenance of storm water management faicilities. A special emphasis will be placed on dual purpose facilities. The manual is scheduled for completion in the Spring of 1988.

2.2 DESIGN CONSIDERATIONS FOR DUAL PURPOSE DETENTION BASIN

A dual purpose detention basin is an impoundment area made by constructing an embankment and/or excavating a pit. The purpose of the basin is to temporarily store storm water runoff in order to promote the settlement of runoff pollutants and to restrict outflows to predetermined levels to reduce local and downstream flooding. The basin stores runoff from a developed site or upland area and rainfall that falls on the impoundment surface. Dual purpose detention basins are usually designed as either dry or wet basins. Dry basins are expected to fully evacuate all stored runoff. Wet basins will retain a permanent pond between storm events. Dual purpose basins may also be built with an infiltration feature rather than a wet basin.

Site Layout

The location of a dual purpose detention basin is extremely important to it's effectiveness. To be able to effectively reduce peak rates of runoff, the basin must be situated to intercept a majority of the site runoff. For effective water quality control, the basin must collect all runoff from the impervious areas of the site. The most important of these are roadways and parking lots. The majority of the key pollutants that are removed by dual purpose detention basins originate on these surfaces.

Runoff from areas uphill or upstream from the development site may be passed through or around the site without detention or storage. This may also be applied to onsite areas that have not been developed such that the runoff potential is increased or the water quality of runoff is degraded.

Site conditions may require a storm water management plan that results in certain developed portions of the site bypassing the storm water control measures. With traditional flood control detention basins, an equivalent volume of off site or upstream runoff can be controlled to offset the release of uncontrolled onsite runoff. Similar exchanges of runoff are possible with dual purpose detention basins. However, the exchange waters must have equivalent water quality characteristics. An acceptable method of evaluating potential water quality for this purpose is to utilize land use categories. For example if the runoff from a parking lot bypasses the dual purpose basin, an equivalent volume of runoff from an upstream parking lot may be substituted. For similar land use categories, the extent of impervious coverage should be used to establish equivalency. Density may be substituted in the use of residential land uses, if appropriate. The procedure is intended to allow exchanges of runoff with similar water quality. However land use may not always be the sole determinant of pollution potential. For example the runoff from the parking lot of an industrial chemical shipping yard can not be considered to have the same water quality potential of runoff from an office building parking lot.

Additional Design Considerations

In order to provide the level of water quality and flood control required by the New Jersey Storm Water Management Regulations, multi stage outlet control structures are usually necessary. A typical discharge structure for a dual purpose detention basin is illustrated in Figure 2-1.

Principal Outlets

The design of principal outlets of most storm water controls is based on reproducing predeveloped flow rates. The New Jersey SWM regulations require the 2-year, 10-year and 100-year predeveloped rates of runoff be used for outlet release rates. Added to the rate control requirement is a standard for water quality enhancement of the runoff of the 1-year storm.

The discharge structure will typically have three principal outlets. The water quality outlet (d1) will usually be small in comparison to the other outlets. The use of a restrictor plate containing an orifice designed to provide the required retention should be used in place of a small pipe in the structure. The restrictor plate can be removed to facilitate maintenance or to allow future alterations of the water quality outlet.

The second and third stage outlets are sized to provide the required reductions in the larger storms. In most cases, the second stage outlet will be designed to act as the primary control for the 10-year storm. The two(2)-year, being so close to the one(1)-year in runoff volume, will be primarily controlled by the water quality outlet and despite some overflow through the second outlet, peak rates are adequately controlled. The third stage outlet is designed to control the 100-year storm. The overflow is normally provided in case of failure of the lower stage outlets, for example due to clogging by debris.

Outlet Protection

In order to reduce the possibility of clogging of the various outlets, trash racks should be installed for each. Two examples of trash racks are shown in Figure 2-1. The inclined vertical bar rack is most effective for the lower stage outlets. Debris will ride up the trash rack as water levels rise. This design also allows for removal of accumulated debris with a rake while standing on top of the structure. Cage type racks or racks with horizontal members inhibit this type of debris removal.

The surface areas of all trash racks should be maximized and the trash racks should be designed to be as far away from the protected outlet

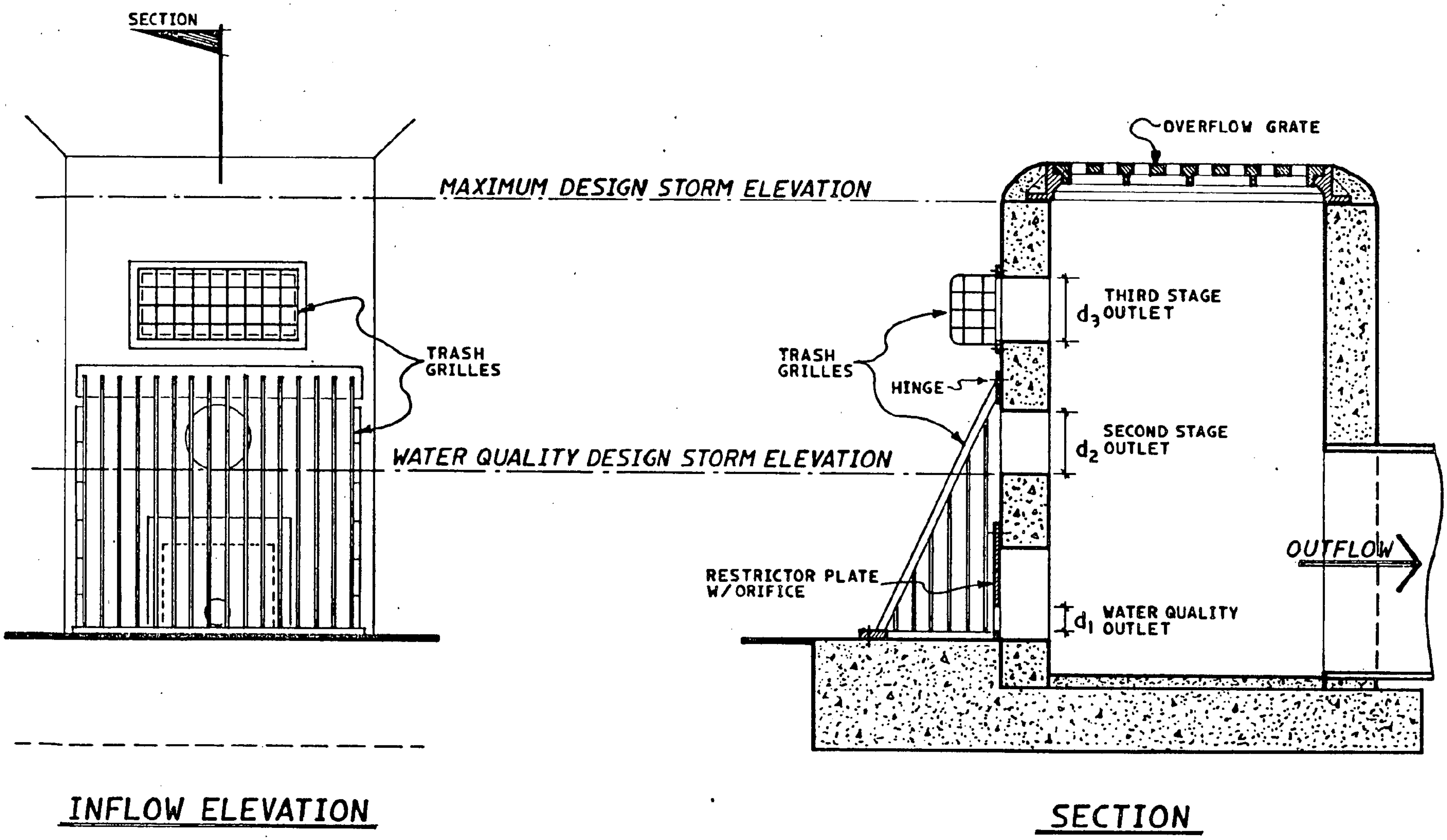

FIGURE 2-1 DIAGRAM MULTIPLE STAGE OUTLET STRUCTURE FOR A DUAL PURPOSE DETENTION BASIN

as possible. This is done to avoid interference with the hydraulic capacity of the outlet. Spacing of the rack bars should be wide enough to also avoid interference. However, the spacing should be close enough to provide the level of clogging protection required.

In order to facilitate removal of accumulated debris and sediment from around the outlet structure, the racks should have hinged connections. If the rack is bolted or set in concrete, it will preclude removal of accumulated material and will eventually adversely effect the hydraulics of the outlet.

Since sediment will tend to accumulate around the lowest stage outlet, the inside of the outlet structure should be depressed below the water quality outlet to minimize clogging of this opening due to sedimentation. Depressing the outlet bottom to a depth below the water quality outlet equal to the diameter of the outlet is recommended (Figure 2-1).

Basin Configuration

The dual purpose detention basin relies on sedimentation for removal of runoff pollutants. In order to maximize the degree of sedimentation achieved, the basin should be designed to lengthen flow paths and increase detention time. The use of long, narrow basin configurations with length to width ratios of 2:1 to 3:1 is recommended. The use of basin designs that are shallow and have large surface areas will also provide better removal efficiencies than small deep basin designs. The ratio of total inflow volume to detained volume is also a significant factor in the removal efficiency of the basin.

The inflow points to the basin should be as far removed from the outlet structure as possible. This will avoid short circuiting of runoff by maximizing flow paths in the basin. Reducing inflow velocities will help lengthen detention times. Rip rap or other energy dissapators should be used at all inflow points. Reduced inflow velocities will minimize resuspension of settled pollutants and increase sedimentation for incoming runoff.

Low Flow Channels

Low flow channels are often required when erosion of the basin floor is a concern. A review of dual purpose detention basins in New Jersey has shown that erosion is no worse in basins without low flow channels than in basins with low flow channels. Where low flow channels are used, gabion lined channels with underdrains are encouraged. Impervious channel linings such as concrete or asphalt are discouraged as they reduce detention times by increasing flow velocities. Pervious channel linings also promote interaction of storm runoff with the soil and grass which increases sorbtion of pollutants to particulates.

Impervious channel linings have been often prescribed for low maintenance , however experience with dual purpose basins in New Jersey has indicated just the opposite. These channels are often undermined by runoff flow; differential settlement is common and these channel linings transport sediment loads to the outlet much more readily than vegetative or gabion lined channels. In the long term, impervious channel linings are probably more of a maintenance problem than not having any low flow channel.

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CHAPTER 3

PLANNING CONSIDERATIONS, INFILTRATION AND VOLUME CONTROLS

3.1 INFILTRATION FEASIBILITY TESTS

In order to comply the requirements of the New Jersey Storm Water Management Regulations or other local requirements, many designers are using infiltration techniques to control runoff. When properly used, the techniques can provide satisfactory results. However, these techniques are not applicable for all control situations.

A number of feasibility requirements can be tested to determine whether a SWM infiltration practice may be constructed on a specific site and to what extent it may be applied. These feasibility tests include:

1. Soil textural classes with minimum infiltration rates that permit adequate percolation of stored runoff.

2. Maximum allowable ponding or storage time within the structure.

3. Available depth between the bottom of the infiltration practice and the seasonal high groundwater table or depth to bedrock.

4. The topographic character of the site including the slope, nature of the soil (natural or fill), and proximity of building foundations, water supply wells and septic fields.

The usage of infiltration practices will depend upon a careful site investigation to determine the conditions in which the feasibility tests will indicate positive results. Each of the above feasibility conditions are to be investigated and each are equally important ensuring the proper functioning of the proposed infiltration practice. Should a site investigation reveal that any one of the feasibility tests is not adequate, the implementation of infiltration practices should not be pursued.In these cases, dual purpose detention basins usually offer the most feasible alternative.

Soil Textures

The hydrologic design methods presented in Chapter 4 are based on the utilization of two hydrologic soil properties, the effective water capacity (C_w) and the minimum infiltration rate (f) of the specific soil textural groups, as shown in Table 3-1. The effective water capacity of a soil is the fraction of

TABLE 3-1 HYDROLOGIC SOIL PROPERTIES CLASSIFIED BY SOIL TEXTURE*

Texture Class	Effective Water Capacity (C_w)	Minimum Infiltration Rate (F)	Hydrologic Soil Grouping
	(in. per in.)	(in. per hr.)	
Sand	0.35	8.27	A
Loamy Sand	0.31	2.41	A
Sandy Loam	0.25	1.02	B
Loam	0.19	.52	B
Silt Loam	0.17	.27	C
Sandy Clay Loam	0.14	.09	C
Clay Loam	0.14	.17	C
Silty Clay Loam	0.11	.06	D
Sandy Clay	0.09	.05	D
Silty Clay	0.09	.04	D
Clay	0.08	.02	D

* Source: Rawls, Brakensiek and Saxton, 1982

Textural Triangle U.S.D.A.

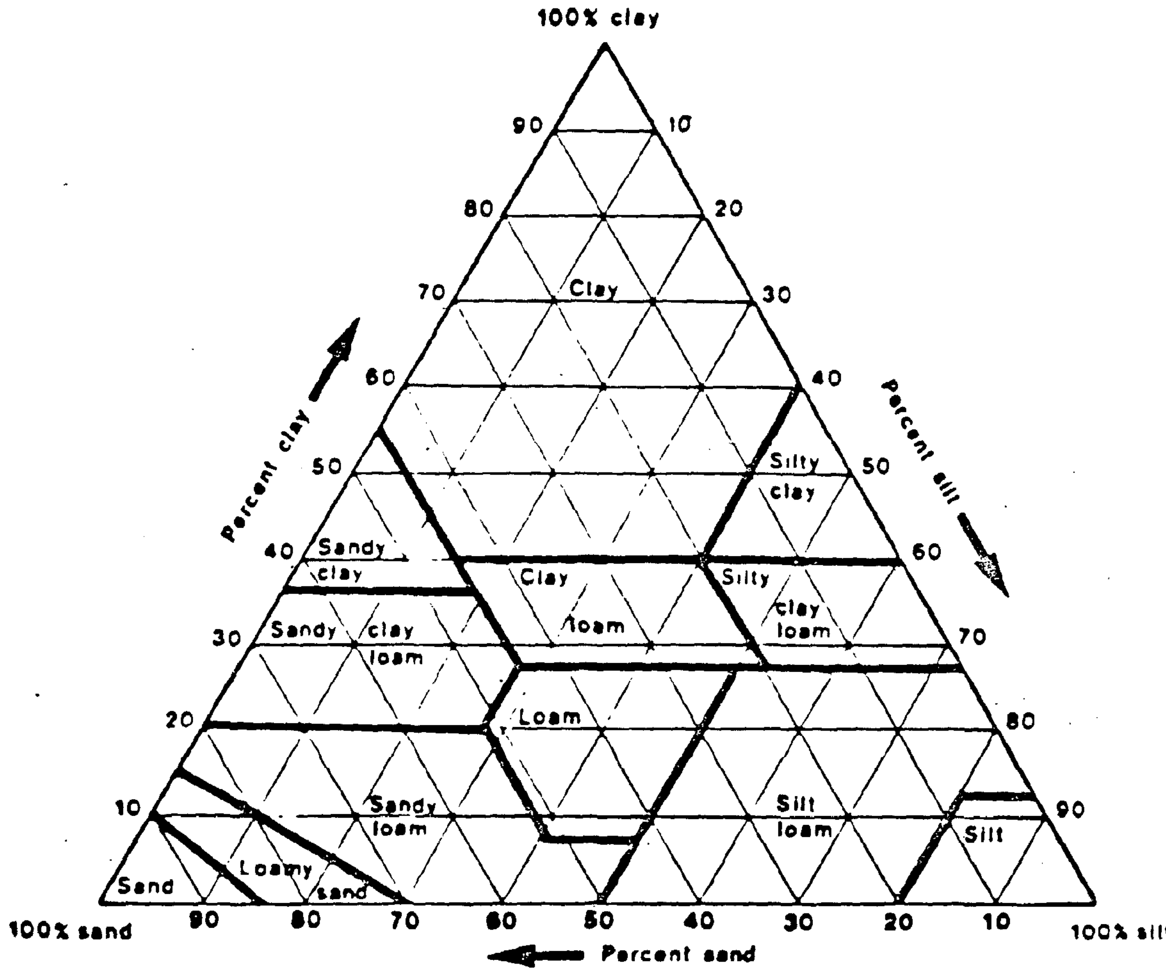

Figure 3-1. U.S.D.A. Textural Triangle

the void spaces available for water storage, measured in terms of inches per inch. The minimum infiltration rate is the final rate that water passes through the soil profile during saturated conditions, measured in terms of inches per hour. The hydrologic soil properties are obtained by identifying the soil textures by a gradation test for each of the changes in soil profile. The soil textures presented in Table 3-1 correspond to the soil textures of the U.S. Dept. of Agriculture (USDA) Textural Triangle presented in Figure 3-1.

The data presented in Table 3-1 are based on the analysis of over 5,000 soil samples under carefully controlled procedures by the USDA. The use of the soil properties established in Table 3-1 for design and review procedures will offer two advantages. First, it will provide for consistency of results in the design procedures. Second, it will eliminate the need for the laborious and costly process of conducting field and laboratory infiltration and permeability tests.

Based on the soil textural classes and the corresponding minimum infiltration rates, a restriction is established to eliminate unsuitable soil conditions. Soil textures with minimum infiltration rates of 0.17 inches per hour or less are not suitable for usage with infiltration practices. These include soils that have a 30 percent clay content, making these soils susceptible to frost heaving and structurally unstable, in addition to having a poor capacity to percolate runoff. Soil textures that are recommended for infiltration systems include those soils with minimum infiltration rates of 0.27 inches per hour or greater, which include silt loam, loam sandy loam, loamy sand, and sand.

Maximum Allowable Ponding or Storage Time

The feasibility criteria for using storm water management infiltration systems can also be based upon the concept of a maximum allowable ponding time (T_p) for surface storage or a maximum allowable storage time (T_s) within a subsurface stone aggregate reservoir. The concept will vary depending upon the storage mechanism of each practice which will govern the available storage within the structure. The established maximum ponding and storage time is a 3 day or 72 hour period in which stored runoff within the structure should be completely drained. The maximum ponding time for vegetated swales is 24 hours. The use of the maximum allowable time frame in conjunction with a specific soil minimum infiltration rate (f) will dictate the maximum allowable design depth (d_{max}) of the structure. The maximum depth of an infiltration basin and a vegetated swale may be defined as:

$$d_{max} = fT_p \qquad (3-1)$$

The maximum depth of an infiltration trench and dry well, will depend upon the void ratio (V_r) of the stone aggregate reservoir and may be defined as:

$$d_{max} = \frac{fT_s}{V_r} \qquad (3-2)$$

The maximum allowable design depths for various soil textures and ponding or storage times are given in Table 3-2 for the criteria in Equations 3-1 and 3-2. The portion of the table that is shaded represents soil infiltration rates that are unacceptable. The maximum design depths will obviously become greater as the minimum infiltration rates of a soil texture class becomes greater. The depth of the structure required for design will depend upon the site characteristic and the level of control. The values of d_{max} in Table 3-2 represent only the upper allowable range for design depth which may be less where other limitations exist (i.e., distance to groundwater).

Depth to High Groundwater Table and Bedrock

An additional feasibility criterion of a storm water management infiltration structure consists of determining the safe distance between the bottom of the structure and the location of the seasonal high groundwater table. This distance is also important in protecting against the flooding of the structure due to the rise of the water table, rendering the structure ineffective. The U.S. Environmental Protection Agency's (EPA) criteria for onsite wastewater treatment and disposal systems specifies that a 2 to 4 foot distance be provided between the bottom of the waste disposal system and the water table or bedrock (EPA, 1980). Thus, it is recommended that infiltration structures be located only in areas where the bottom of the structure will be 2 to 4 feet above the seasonally high groundwater table and/or bedrock.

Data on the application of secondary effluent to land disposal systems suggests that a 2 to 3 foot depth is generally sufficient to remove most pollutants (COG, 1980). Experience on Maryland's Eastern Shore, where high water table conditions are common, indicates that septic systems can be successfully designed and built with less distance than generally recommended by rules of thumb. In addition, the use of vegetated swales on the Eastern Shore is a common drainage technique which has been used successfully to convey runoff, although during high water table conditions they become saturated. Thus, the use of swales as a storm water management infiltration practice may still be encouraged in cases where the distance to the water table is on the order of 1 to 2 feet. The surface geology and soil textures of the coastal plain of New Jersey are sufficiently similar to

TABLE 3-2. MAXIMUM ALLOWABLE DEPTHS (INCHES) OF STORAGE FOR TWO CRITERIA, SELECTED MAXIMUM PONDING OR STORAGE TIMES (T_p OR T_s IN HOURS), MINIMUM INFILTRATION RATES (INCHES/HOURS)

Criterion	T_p or T_s (hrs)	SOIL TEXTURE/F (INCHES/HOUR)										
		Sand	Loamy Sand	Sandy Loam	Loam	Silt Loam	Sandy Clay Loam	Clay Loam	Silty Clay Loam	Sandy Clay	Silty Clay	Clay
		8.27	2.41	1.02	.52	.27	.17	.09	.06	.05	.04	.02
fT_p	24	198	58	24	13	6	4					
	48	397	116	49	25	13	8	4	3			
	72	595	174	73	37	19	12	6	4	4	3	1
fT_s/V_r for (V_r = 0.4)	24	496	145	61	31	16	10	5	4	3	2	1
	48	992	290	122	62	32	20	11	7	6	6	2
	72	1489	434	183	93	49	31	16	11	9	7	4

Note: T_p = Maximum allowable ponding time

T_s = Maximum allowable storage time

V_r = Voids ratio

(hatched) These values represent unfeasible solutions

Maryland's Eastern Shore that these guidelines are applicable and should be used for design criteria in New Jersey.

Topographic Conditions

The topographic conditions of the site represent feasibility factors that need to be examined prior to incorporating infiltration systems on specific sites. These include the slope, nature of the soil (natural or fill), and the proximity of building foundations, water supply wells and septic systems. If local health authorities document existing problems regarding water supply well pollution resulting from infiltration practices, infiltration shall not be utilized.

The use of a particular practice will place a restriction on the allowable slope. The use of vegetated swales, for example, requires a relatively level or gently sloping area not to excess of 5 percent (20h:1v). All other infiltration practices shall be located in areas in which the slope does not exceed 20 percent (5h:1v). Application of infiltration practices on a steep grade increases the chance of water seepage from the subgrade to the lower areas of the site and reduces the amount which infiltrates.

Developments occurring on sloping and rolling sites often require the use of extensive cut and fill operations. The use of storm water management infiltration systems on fill material is not recommended due to the possibility of creating an unstable subgrade. Fill areas can be very susceptible to slope failure due to slippage along the interface of the in-situ and fill material. This condition could be aggravated if the fill material is allowed to become saturated by using infiltration practices.

The proximity of building foundations should be at least 10 feet up gradient from infiltration systems to prevent the possibility of flooding basements. The proximity of septic systems is also a concern and local health officials should be consulted for guidance on minimum setbacks. Additionally, the location of infiltration practices shall be a minimum of 100 feet from any water supply well where the runoff is from commercial or industrial impervious parking areas.

Other Considerations

In addition to the feasibility criteria presented above, there are a number of other factors to be considered in evaluating the use of infiltration practices. A number of localities have regulations which require the use of curb and gutter for all subdivision development. Unless this requirement is changed, it will cause a conflict with the use of vegetated swales. Some localities have regulations which prevent the connection of roof drains to dry wells. Also, some localities have requirements that all structures have a positive drain outlet. These requirements seriously limit the use of infiltration practices.

Construction

Regardless of the type of storm water management practice to be constructed, careful considerations must be given in advance of construction to the effects of the work sequence, techniques, and equipment employed on the future maintenance of the practice. Serious maintenance problems can be averted, or in large part, mitigated, by the adoption of relatively simple measures during construction.

Previous experience with infiltration practices in New Jersey has shown that storm water management infiltration practices must not be constructed until the drainage areas contributing to the structure have been adequately stabilized. When this precaution has not been taken, the infiltration structure has often become clogged with sediment from the construction operations upland and thus failed to operate from the outset.

Specific construction methods and specifications are provided in the remainder of this chapter for each individual storm water management practice.

Maintenance

The maintenance requirements of storm water management practices are an important aspect which are often not addressed in the planning and design of these structures. Detention and infiltration basins, vegetated swales, and vegetative buffers can be visually inspected and easily maintained. Infiltration trenches and dry wells, once installed, are very difficult to inspect and maintain. Consequently, these latter practices should be designed using inlet structures, sediment and grease traps and vegetated filters which will protect the integrity of the practice, ensure a long functional life, and provide readily accessible structures for maintenance.

Specific maintenance specifications and recommendations are provided for each individual storm water management practice in the remainder of this chapter.

The New Jersey Division of Water Resources and Ocean County are conducting a study on the maintenance considerations of storm water management controls. A maintenance manual will be developed during this study. The study (and manual) will cover a number of issues, including the relationship of designs to maintenance, the legal and institutional aspects of maintenance and long term financing of maintenance programs. The study is scheduled for completion in the Spring of 1988.

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3.2 INFILTRATION BASIN

(IB)

Description

An infiltration basin is a water impoundment made by constructing a dam or an embankment or by excavating a pit or a dugout in or down to relatively permeable soils. The purpose of the basin is to temporarily store the surface runoff for a selected design storm and to maintain or increase ground water recharge by infiltration through the bed and sides of the basin.

Applicability

An infiltration basin will generally be used in the same manner as a detention basin. The infiltration basin will typically be constructed in drainage areas of up to 50 acres. An infiltration basin may be constructed jointly with a detention basin by raising the outlet pipe.

Planning Considerations

An infiltration basin has relatively large surface area requirements in comparison to either an infiltration trench or a dry well. Whereas a trench or a dry well is generally associated with small drainage areas of 1 acre or less, infiltration basins are better suited to control larger drainage areas generally ranging from 5 to 50 acres in size.

A typical infiltration basin will range from 3 to 12 feet in depth. The seasonally high groundwater table should be located at least 2 to 4 feet below the bottom of the basin. Similarly, bedrock should also be located at least 2 to 4 feet below the bottom of the basin.

The permeability or final infiltration rate of the various soil types will determine how rapidly the stormwater ponded in the basin at the end of the storm will be infiltrated into the ground. Table 3-2 provides the maximum allowable depth of ponding for the various soil textures for a range of allowable ponding times. The table indicates that for soil textural classes with final infiltration rates (f) of 0.52 in/hr and larger allow for the design of basins with a ponding depth of approximately 3 feet and deeper, provided that the criteria for depth to higher water table and bedrock are satisfied.

The soil textural class with an f value of 0.27 inches per hour (silt loam) may have some limited suitability for a very shallow infiltration basin. This shallow basin will of course control a smaller drainage area than the deeper basins and thus will require more surface are to provide an equivalent level of control. Due to the high cost of land being converted to urban uses, the designer or developer will generally seek to minimize land costs by using fewer, smaller and deeper basins. This constraint will make soils with infiltration rates less 0.27 inches per hour unsuitable for use of infiltration basins. The infiltration capacities of soils which allows them to infiltrate 36 inches of stored runoff over a 3 day period makes them well suited for an infiltration basin.

Design Criteria

The design of infiltration basins will follow the criteria outlined in Chapter 4 or subsequent revisions for embankment design, in conjunction with an adequate, non-erosive outlet channel, and the additional criteria set forth below.

Design Storm

All hydrologic and hydraulic calculations shall be based on the design storm criteria provided in the New Jersey State Storm Water Management Regulations N.J.A.C. 7:8.

Ponding Time

All infiltration basins shall be designed to completely drain stored runoff within 3 days following the occurrence of a storm event. Thus an allowable maximum ponding time T_p of 72 hours shall be used.

Water Table, Bedrock, and Groundwater Conditions

Infiltration basins should be located only in areas where the bottom of the basin will be at least 2 to 4 feet above the seasonally high groundwater table or bedrock at all times. Also infiltration basins shall be located at least 100 feet horizontally away from any water supply well.

Concerns related to the development of a groundwater mound below the infiltration facility as well as the potential for polluting downgradient groundwater supplies often arise when infiltration facilities are considered. The data base evaluated in the preparation of these specifications indicates that due to the intermittent nature of precipitation patterns and the associated operation of infiltration practices, groundwater mounding has not been observed to be a problem where such facilities have been properly designed and constructed. Also, the data base indicates that groundwater pollution has not been observed to be a problems with most residential and commercial land uses.

Runoff Filtering

Grease, oil, floatable organic materials, and settleable solids should be removed from runoff water before it enters the infiltration basin. These materials can take up storage capacity and reduce infiltration rates.

Runoff filtering devices such as vegetative filters (see Section 3.6), sediment traps, and grease traps can be used to remove objectionable materials. In addition, modified basin designs such as illustrated in Figures 3-2a and 3-2b can be used to enhance and prolong the infiltration capacity of the basin bottom. Even when the basin bed becomes clogged by layers of accumulated sediment, infiltration can still be achieved through the sides of the basins, as shown in Figure 3-3, provided that the side materials are relatively permeable.

When a runoff filtering system or structure is included in the design, the maintenance requirements and schedule of the filter structure must be included.

Principal Spillway for Combination Structure

When basins are designed to infiltrate the water quality design storm runoff the bottom elevation of the low-stage orifice should be designed to coincide with the volume of runoff produced by the water quality design storm. If the water volume requirements exceed the 3-day infiltration capacity of the system, additional or alternate water quality controls must be investigated. All other aspects of the principal spillway design will follow the guidelines provided in the standards and specifications for Dual Purpose Detention Basins.

Emergency Spillway

An emergency spillway shall be provided for all basins created by an embankment. All excavated basins shall have a nonerosive outlet channel. The emergency spillway design shall comply with the requirements of the standards and specifications for Dual Purpose Detention Basins.

Vegetation

The embankment, emergency spillway, spoil and borrow areas, and other disturbed areas shall be stabilized and planted in accordance with the appropriate vegetative measure standards in the New Jersey Standards and Specifications for Soil Erosion and Sediment Control. The emergency spillway is often the most critical area. Additional, a grass strip or other vegetative buffer at least 20 feet wide shall be provided around the basin to protect against erosion.

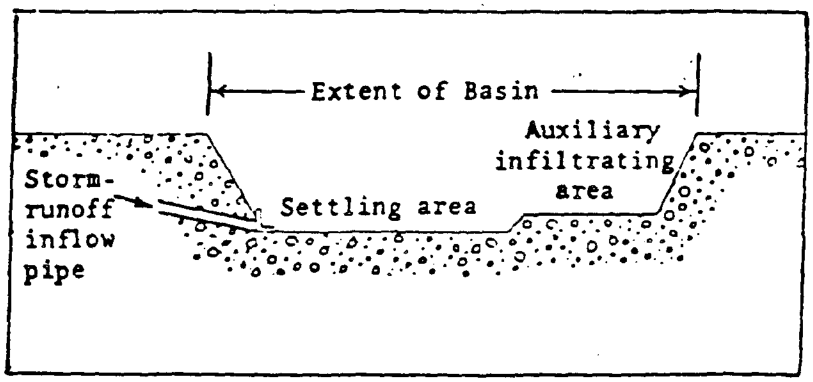

Figure 3-2a. Two-level Infiltration Basin.

Source: Aronson and Seaburn, 1969

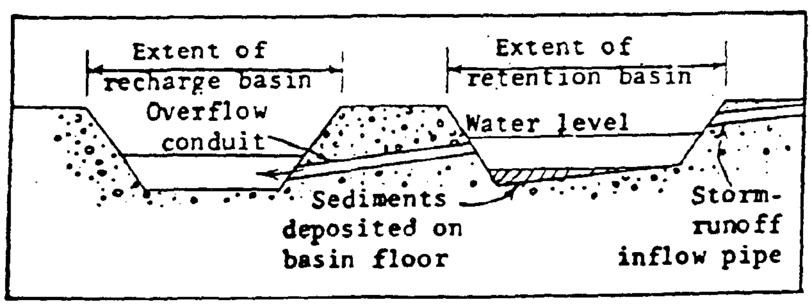

Figure 3-2b. Retention Basin and the Adjoining Infiltration Basin.

Source: Modified After Aronson and Seaburn, 1969

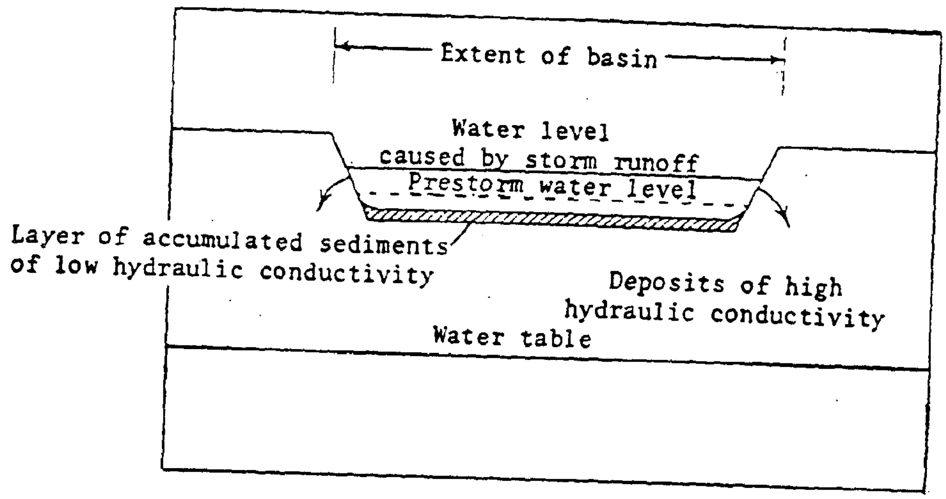

Figure 3-3. Water-containing Infiltration Basin illustrating Storm Water Disposal through the Sides of the Basin above the Level of accumulated Material of Low Hydraulic Conductivity.

Source: Aronson and Seaburn, 1969

Fencing

The embankment and basin shall be fenced where and when deemed necessary by the land developer or local jurisdiction to provide public safety or protection of vegetation.

Hydrologic Design Method

A recommended hydrologic design method based on SCS TR-55 procedures is provided in Chapter 4, Hydrologic Design Methods, Infiltration and Volume Controls.

Water Quality

The effectiveness of this practice for runoff and pollution control is dependent upon the size and design of the infiltration facility. If a basin is designed to collect and infiltrate the storm runoff from the water quality design storm over a given drainage area, the practice should be effective for pollution abatement for storms up to and including the design storm. The quality requirements of the New Jersey State Storm Water Management regulations will be satisfied as long as the use of the infiltration practice results in zero runoff from the site under conditions of the water quality design storm.

Construction Specifications

The construction of all infiltration basins should comply with the criteria set forth in the standards and specifications for Dual Purpose Detention Basins or subsequent revisions and the additional criteria provided below.

Schedule

The sequence of various phases of basin construction shall be coordinated with the overall project construction schedule. A program should schedule rough excavation of the basin with the rough grading phase of the project to permit use of the material as fill in earthwork areas. The partially excavated basin could serve as a sedimentation basin in order to assist in erosion and sediment control during construction. However, basins near final stages of excavation should never be used prematurely for runoff disposal. Drainage from untreated, freshly constructed slopes within the watershed area would load the newly formed basin with a heavy concentration of fine sediment. This could seriously impair the natural infiltration characteristics of the basin floor. Final grade of an infiltration basin shall not be attained until after its use as a sediment control basin is completed.

Specifications for basin construction should state: (1) the earliest point in progress when storm drainage may be directed to the basin, and (2) the means by which this delay in use is to be accomplished. Due to the wide variety of conditions encountered among projects, each should be separately evaluated in order to postpone use as long as is reasonably possible.

Excavation

Initial basin excavation should be carried to within 1 foot of the final elevation of the basin floor. Final excavation to the finished grade should be deferred until all disturbed areas on the watershed have been stabilized or protected. The final phase excavation should remove all accumulated sediment. Relatively light tracked equipment is recommended for this operation to avoid compaction of the basin floor. After the final grading is completed, the basin floor should be deeply tilled by means of rotary tillers or disc harrows to provide a well-aerated, highly porous surface texture.

Lining Material

Infiltration basins may be lined with a 6- to 12-inch layer of filter material such as coarse sand to help prevent the buildup of impervious deposits on the soil surface. The filter layer can be replaced or cleaned when it becomes clogged. When a 6-inch layer of coarse organic material is specified for discing (such as hulls, leaves, stems, etc.) or spading into the basin floor to increase the permeability of the soils, the basin floor should be soaked or inundated for a brief period, then allowed to dry subsequent to this operation. This induces the organic material to decay rapidly, loosening the upper soil layer.

Establishing dense vegetation on the basin side slopes and floor is recommended. A dense vegetative stand will not only prevent erosion and sloughing, but will also provide a natural means of maintaining relatively high infiltration rates. Erosion protection of inflow points to the basin shall also be provided. Removal of accumulated sediment is a problem only at the basin floor. Little maintenance is normally required to maintain the infiltration capacity of slope areas.

Selection of suitable vegetative materials for the side slope and all other areas to be stabilized with vegetation and application of required fertilizer and mulches shall be done in accordance with the New Jersey Standards and Specifications for Soil Erosion and Sediment Control. Local Extension Agencies should also be consulted.

Visual Resource Design

The visual design of basins in areas of high public visibility shall be carefully considered for aesthetic quality. The underlying criterion for all visual design is appropriateness. The shape and form of a basin, excavated material, and planting area to relate visually to their surroundings and to their function.

The embankment may be shaped to blend with the natural topography. The edge of the basin may be shaped so it is generally curvilinear rather than rectangular. Excavated material can be shaped so that the final form is smooth, flowing, and fitting to the adjacent landscape rather than angular geometric mounds.

Maintenance

Inspection Schedule

Drainage systems must be inspected on a routine basis to ensure that they are functioning properly. Inspections can be on a semiannual basis but should always be conducted following major storms.

Sediment Control Effect on Vegetated Basins

Cleanout frequency of infiltration basins will depend on whether they are vegetated or nonvegetated and will be a function of their storage capacity, recharge characteristics, volume of inflow, and sediment load. Infiltration basins should be inspected at least once a year. Sedimentation basins and traps may require more frequent inspection and cleanout.

Grass bottoms on infiltration basins seldom need replacement since grass serves as a good filter material. This is particularly true of Kentucky 31 Tall Fescue, which is extremely hardy and can withstand several days of submergence. If silty water is allowed to trickle through the turf, most of the suspended material is strained out within a few yards of surface travel. Well established turf on a basin floor will grow up through sediment deposits, forming a porous turf and preventing the formation of an impermeable layer. Grass filtration would work well with long, narrow, shoulder-type (swales, ditches, etc.) depressions where highway runoff flows down a grassy slope between the roadway and the basin. Kentucky 31 Tall Fescue demands very little attention and looks attractive when trimmed. Grass planted on basin side slopes will also prevent erosion.

Sediment Removal From Nonvegetated Basin

(a) Technique. Remove sediment only when the basin floor is completely dry, after the silt layer has mud-cracked and separated from the basin floor. Equipment maneuverability and precise blade control are essential in small areas and can greatly reduce the quantity of material to be removed.

(b) Frequency. All sediment must be removed prior to tilling operations. As tilling is required periodically and at least once annually, the frequency of sediment removal will be reduced to small operations on a regular basis.

Tilling of Nonvegetated Basin Floor

In all cases, tilling must be preceded by thorough removal of surface sediment as previously above.

(a) Purposes. It is necessary to restore the natural infiltration capacity by overcoming the effects of surface compaction, and to control weed growth on the basin floor.

(b) Technique. Rotary tillers or disc harrows normally serve this purpose. Light tractors should be employed for these operations. In the event that heavy equipment has caused deeper than normal compaction of the surface, these operations could be preceded by deep plowing. In its final condition after tilling, the basin floor should be level, smooth, and free of ridges and furrows to ease future removal of sediment and minimize the material to be removed during future cleaning operations. A levelling drag, towed behind the equipment on the last pass, will accomplish this.

(c) Frequency. In the spring, the basin surface is usually quite porous due to the effects of frost and subsequent thawing. The infiltration capacity diminishes rapidly thereafter. To enhance infiltration capacity, tilling should be thorough once each season, from late June through September. To control vegetative growth, an additional light tillage may be advisable during the growing season. Precautions must be observed, however, to avoid any possibility of working sediment accumulations into the basin floor as a part of light cultivation for the purpose of weed control. It is therefore stressed again that any cultivation or tilling operation be preceded in all cases by careful sediment removal.

Side Slope Maintenance

(a) Purpose. To promote a dense turf with extensive rootgrowth, thereby enhancing infiltration through the slope surface and prevent weeds from gradually taking over the slope areas.

(b) Frequency. Grasses of the fescue family are recommended for seeding primarily due to their adaptability to dry sandy soils, drought resistance, hardiness, and ability to withstand brief inundations. The use of fescues will also permit long intervals between mowings. This is important due to the relatively steep slopes which make mowing difficult. Mowing twice a year, once in June and again in September, is generally satisfactory. Refertilization with 10-6-4 ratio fertilizer at a rate of 500 lb per acre (11 lb per 1000 sq ft) may be required the second year after seeding.

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3.3 INFILTRATION TRENCH

(IT)

Description

An infiltration trench consists of a shallow excavated trench, generally 2 to 10 feet in depth backfilled with a coarse stone aggregate, allowing for temporary storage of storm runoff in the voids between the aggregate material. Stored runoff then gradually infiltrates into the surrounding soil. Figure 3-4 provides a typical section of infiltration trenches.

The surface of the trench will consist of stone, gabion, sand, or a grassed covered area with a surface inlet.

Applicability

An infiltration trench will generally be used on relatively small drainage areas. This practice can be used on residential lots, commercial areas, parking lots and open space areas. A trench may also be installed under a swale to increase the storage of the infiltration system.

Planning Considerations

Soil Permeability

The permeability or final infiltration rate of the various soil textural classifications will be a limiting factor in the selection of infiltration trenches by itself. The infiltration rate becomes a factor when combined with other considerations such as 1) minimum construction depth, 2) maximum allowable storage time, and 3) surface are requirements for a specified level of control. Soil textural classes with infiltration rates greater or equal to 0.27 inches per hour can be considered for use of infiltration trenches.

Depth of Trench

An infiltration trench is projected to range from 2 to 10 feet in stone reservoir depth. A trench with a grassed covered surface will consist of at least one foot of overlying soil above the aggregate reservoir. This 3 foot depth of aggregate is felt to represent the shallowest infiltration trench likely to be built. In general, the design engineer will seek to make the trench as deep as possible to minimize the surface area of the trench.

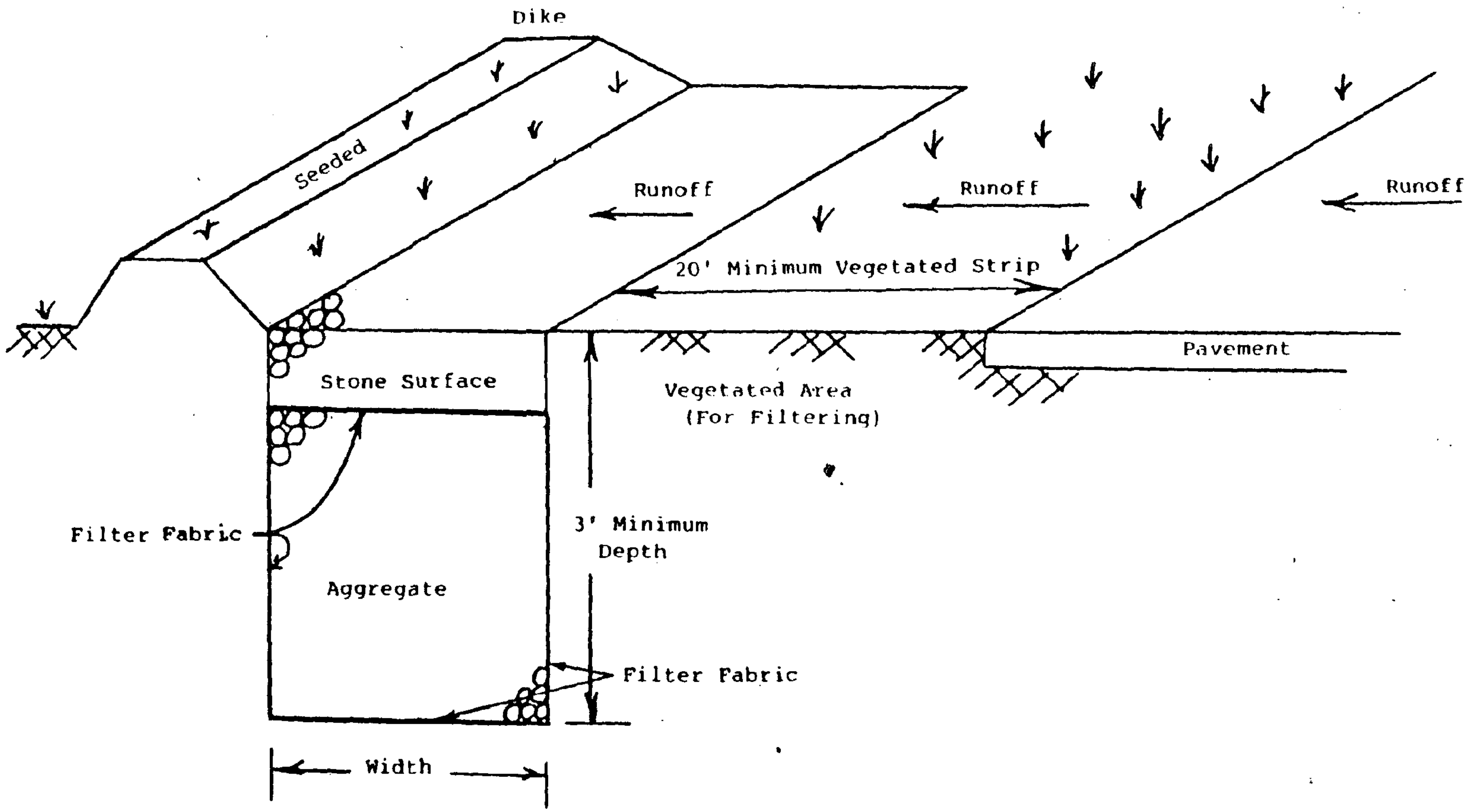


Figure 3-4. Typical Section of Infiltration Trenches
Modified after Frederick Co., MD. (1979)

The final infiltration rate of the soil below the infiltration trench will dictate the maximum allowable trench depth. The maximum storage depth of the trench.

Water Table, Bedrock, and Groundwater Conditions

The seasonally high ground water table as well as bedrock should be located at least 2 to 4 feet below the bottom of the trench at all times. Therefore these two parameters may often determine the maximum allowable depth for the trench. Also infiltration trenches shall be located at least 100 feet horizontally away from any water supply well.

Design Criteria

Design Storm

All hydrologic and hydraulic calculations shall be based on the design storm criteria provided in the New Jersey SWM Regulations N.J.A.C. 7:8.

Storage Time

All infiltration trenches shall be designed to completely drain stored runoff in 3 days. Thus the maximum allowable storage time T_s of 72 hours shall be used.

Backfill Material

The aggregate material for the infiltration trench shall consist of a clean aggregate with a maximum diameter of 3" and a minimum diameter of 1 - 1/2". The aggregate should be graded such that there will be few aggregates smaller than the selected size. Void space for these aggregates are assumed to be between the range of 30 to 40 percent. Quarry blends and road mixes shall not be used.

The aggregate fill material shall be completely surrounded as shown in Figure 3-4 with an engineering filter fabric. In the case of an aggregate surface, filter fabric should surround all of the aggregate fill material except for the top one foot.

Runoff Filtering

At all times, grease, oil, floatable organic materials, and settleable solids should be removed from runoff water before it enters the infiltration facility. These materials can take up storage capacity and reduce infiltration rates. Runoff filtering devices such as grass filter strips and sediment traps can be used to remove objectionable materials. The design and construction of vegetated filter strips is described in this chapter. All trenches with surface inlets shall be designed to capture sediment before discharging into the stone aggregates.

The use of infiltration trenches in combination with swales with check dams is recommended. In this situation the trench should be constructed below the swale. The pool created by the check dam will increase the volume of runoff infiltrated into the trench.

Overflow Channel

In general, because of the small drainage areas controlled by the infiltration trench, an emergency spillway is not necessary. In all cases, though, the overland flow path of surface runoff exceeding the capacity of the trench should be evaluated to preclude the development of uncontrolled, erosive concentrated flow. A non-erosive overflow channel leading to a stabilized watercourse shall be provided for the runoff from the larger design storms.

Seepage Analysis and Control

An analysis shall be made to determine any possible adverse effects of seepage zones when there are nearby building foundations, basements, roads, parking lots, or sloping sites. Developments on sloping sites often require the use of extensive cut and fill operations. The use of infiltration trenches on fill sites with steep slopes is not permitted. Fill areas can be very susceptible to slope failure due to slippage along the interface of the in-situ and fill material. This condition could be further aggravated if the fill material is allowed to saturate. The methods for seepage analysis and estimation of infiltration rates using Darcy's law and flow nets can be used to conduct the seepage analysis.

When infiltration trenches are used in residential areas, special care must be taken to prevent seepage from the trenches causing wet basements. Infiltration trenches 3 or more feet deep shall be located at least 10 feet down gradient from foundation walls.

Hydrologic Design Methods

A recommended hydrologic design method based on SCS procedure is provided in Chapter 4.

Observation Well

An observation well shall be installed in every infiltration trench. The observation well will serve two primary functions: 1) it will indicate how quickly the trench dewaters following a storm and 2) it will provide a method of observing how quickly the trench fills up with sediments.

The observation well should consist of perforated PVC pipe, 4 to 6 inches in diameter. It should be located in the center of the structure and be constructed flush with the ground elevation of the trench as shown in Figure 3-5. The top of the well shall be capped to discourage vandalism and tampering.

Water Quality

The effectiveness of this practice for runoff and pollution control is dependent upon the size and design of the infiltration facility. If a trench or a series of trenches are designed to collect and infiltrate the total volume of runoff for the water quality design storm over a given drainage area, the practice will be effective both runoff control and pollution abatement for storms up to and including the design storm. The water quality requirements of the New Jersey State Storm Water Management regulations will be satisfied as long as the infiltration practices results in zero runoff from the site under conditions of the water quality design storm.

Construction Specifications

Timing

An infiltration trench shall not be constructed or placed in service until all of the contributing drainage area has been stabilized and approved by the responsible inspector.

Trench Preparation

Excavate the trench to the design dimensions. Excavated materials shall be placed away from the trench sides to enhance trench wall stability. Large tree roots must be trimmed flush with the trench sides in order to prevent fabric puncturing or tearing during subsequent installation procedures. The side walls of the trench shall be roughened where sheared and sealed by heavy equipment.

Fabric Laydown

The filter fabric must be cut to the proper width prior to installation. The cut width must include sufficient material to conform to trench perimeter irregularities and for a 6-inch minimum top overlap. Place the fabric roll over the trench and unroll a sufficient length to allow placement of the fabric down into the trench. Stones or other anchoring objects should be placed on the fabric at the edge of the trench to keep the lined

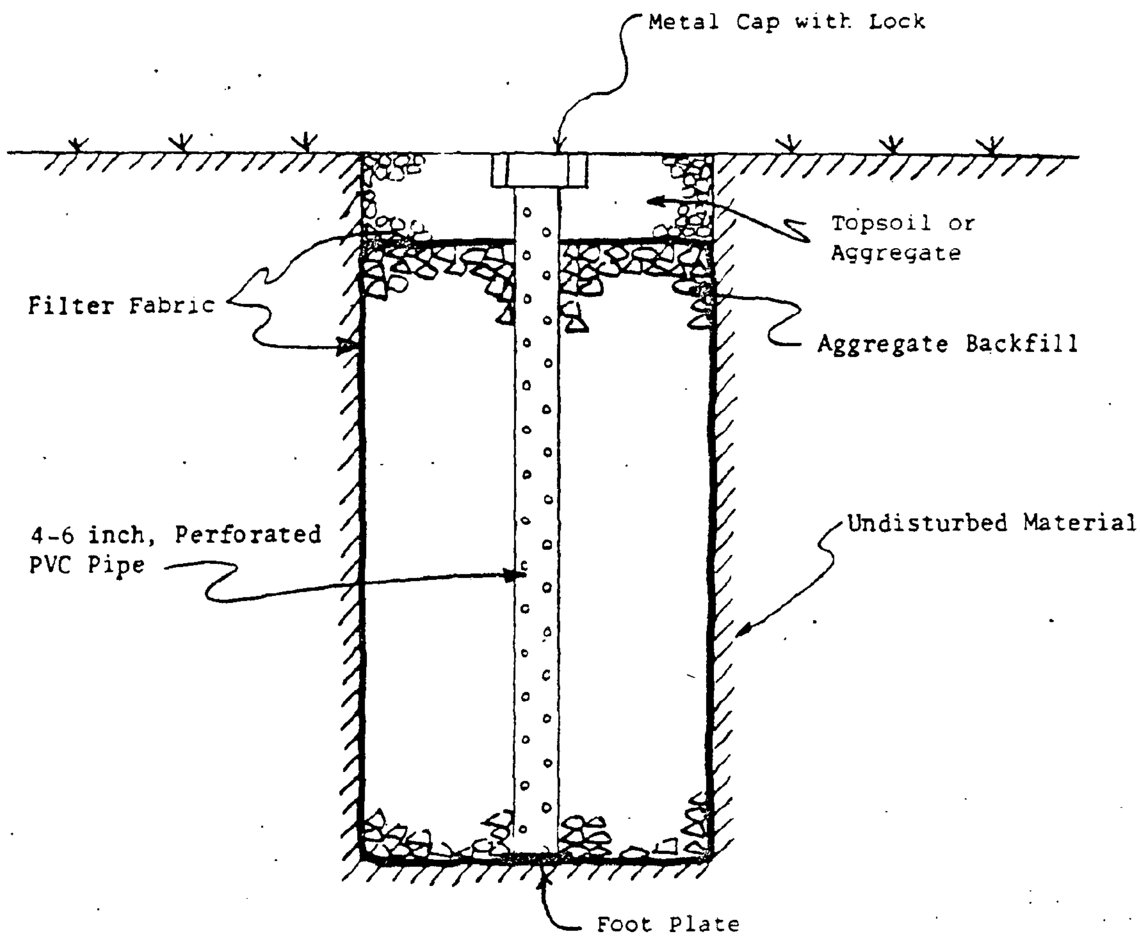


Figure 3-5. Observation Well Detail

trench open during windy periods. When overlaps are required between rolls, the upstream roll should lap a minimum of 2 feet over the downstream roll in order to provide a shingled effect. The overlap ensures fabric continuity or to ensure that the fabric conforms to the excavation surface during aggregate placement and compaction.

Stone Aggregate Placement and Compaction

The stone aggregate should be placed in lifts and compacted using plate compactors. As a rule of thumb, a maximum loose lift thickness of 12 inches is recommended. The compaction process ensures fabric conformity to the excavation sides, thereby reducing the potential for soil piping, fabric clogging, and settlement problems.

Overlapping and Covering

Following the stone aggregate placement, the filter fabric shall be folded over the stone aggregate to form a 6" minimum longitudinal lap. The desired fill soil or stone aggregate shall be placed over the lap at sufficient intervals to maintain the lap during subsequent backfilling.

Contamination

Care shall be exercised to prevent natural or fill soils from intermixing with the stone aggregate. All contaminated stone aggregate shall be removed and replaced with uncontaminated stone aggregate.

Voids Behind Fabric

Voids can be created between the fabric and excavation sides and shall be avoided. Removing boulders or other obstacles from the trench walls is one source of such voids. Natural soils should be placed in these voids at the most convenient time during construction to ensure fabric conformity to the excavation sides. Soil piping, fabric clogging, and possible surface subsidence will be avoided by this remedial process.

Unstable Excavation Sides

Vertically excavated walls may be difficult to maintain in areas where the soil moisture is high or where soft cohesive or cohesionless soils predominate. These conditions may require laying back of the side slopes to maintain stability; trapezoidal rather than rectangular cross sections may result.

Vegetative Buffer

A vegetative buffer of at least 20 feet (wider, if possible) shall be used to intercept surface runoff from all impervious areas, as shown in Figure 3-4.

Traffic Control

Heavy equipment and traffic shall be restricted from travelling over the infiltration areas to minimize compaction of the soil.

Observation Well

An observation well, as described earlier and in Figure 3-5 shall be provided. The depth of the well at the time of installation will be clearly marked on the well cap.

Maintenance

Infiltration trenches shall be designed to minimize maintenance. However, it is recognized that all infiltration facilities are subject to clogging by sediment, oil, grease, grit and other debris. In addition, the performance and longevity of these structures is not well documented. Consequently, a monitoring observation well is required for all infiltration structures.

The observation well shall be monitored periodically. For the first year after completion of construction, the well should be monitored on a quarterly basis and after every large storm. It is recommended that a log book be maintained indicating the rate at which the facility dewaters after large storms and the depth of the well for each observation. Once the performance characteristics of the structure have been verified, the monitoring schedule can be reduced to an annual basis, unless the performance data indicate that a more frequent schedule is required.

Sediment build-up in the top foot of stone aggregates or the surface inlet should be monitored on the same schedule as the observation well. A monitoring well in the top foot of stone aggregate will be required when the trench has a stone surface. Sediment deposited shall not be allowed to build up to the point where it will reduce the rate of infiltration into the trench.

References

1. Stormwater Management design Manual for Frederick Co., Maryland, 1979.

2. Anonymous, Controlling Stormwater Runoff in Developing Areas: Selected Best Management Practices, Metropolitan Washington Council of Governments, July, 1979.

3. Percolation Pits; Their Design, Construction, Use and Maintenance for Stormwater Disposal, Ground Water Recharge, and Surface Water Quality Protection in Adams County, Colorado, Adams County Planning Department.

3.4. DRY WELL

(DW)

Description

A dry well consists of a small excavated pit backfilled with aggregate. The dry well is similar to the infiltration trench previously described but differs in two ways. The dry well is generally a much smaller structure particularly with respect to the surface area dimensions. The depth of the well will generally range from 3 to 12 feet. An important difference between the dry well and the trench is the inflow mechanism. Inflow to the dry well will occur by means of an inflow pipe and through surface infiltration. As previously described, the infiltration trench can only accept inflow through surface or inlet inflow. A typical dry well cross section is presented in Figure 3-6.

Applicability

A dry well will generally be used to capture and store runoff from roof top areas of less than one acre in surface area. This practice can be used to store runoff from residential, commercial, industrial, and institutional roof tops. A secondary application can be built as open-bottomed structures to provide for infiltration of stormwater as shown in Figure 3-7. This secondary application can be utilized for complying with the water quality requirements of N.J.A.C. 7:8.

For both areas of application, the site conditions must include soils that are suitable for infiltration with sufficient depth available between the bottom of the well and the top of the groundwater table.

Planning Considerations

Soil Permeability

The permeability or final infiltration rate of the various soil textural classifications will be a limiting factor in the selection of dry wells. The infiltration rate becomes a factor when combined with other considerations such as: 1) minimum construction depth, 2) maximum allowable storage time, and 3) surface area requirements for a specified level of control. Soil textural classes with infiltration rates greater or equal to 0.27 inches per hour are acceptable for use of dry wells.

Depth of Well

A dry well is expected to range from 3 to 12 feet in depth. In all cases the top foot of the well will consist of a soil filter medium. Thus, a 3 foot deep well would consist of 1 foot of soil filter media and 2 feet of aggregate storage area. This 3 foot depth is felt to represent the shallowest dry well likely to be built. In general, the developer and design engineer will seek to make the dry well as deep as possible to obtain the maximum are of control possible. Table 3-2 indicates that a silt loam soil texture with an f value of 0.27 inches per hour can drain a 4-foot deep storage area in a 72-hour period.

The maximum depth of dry wells will generally be determined bv a number of factors. These include: 1) the soil textural characteristics and 2) the depth of the water table or bedrock.

Water Table, Bedrock, and Groundwater Conditions

The bottom of the dry well shall be located at least 2 to 4 feet above the seasonally high groundwater table as well as bedrock. Therefore, these two parameters will often determine the maximum allowable depth for the well. Also dry wells shall be located at least 100 feet horizontally away from any water supply well.

Design Criteria

Design Storm

All hydrologic and hydraulic calculations shall be based on the design storm criteria provided in the New Jersey SWM Regulations. N.J.A.C. 7:8

Storage Time

All dry wells shall be designed to be empty within 3 days from the beginning of the storm. Thus an allowable storage time T_s of 72 hours shall be used.

Backfill Material

The aggregate fill material for the infiltration trench shall consist of a clean aggregate with a maximum diameter of 3" and a minimum diameter of 1-1/2". The aggregate should be poorly graded with a few stones smaller than the selected size. Void space for these aggregates are assumed to be between the ranges of 30 to 40 percent. Quarry blends or quarry process mixes should be avoided.

Any stone aggregate shall be completely surrounded with an engineering filter fabric as shown in Figure 3-6.

Runoff Filtering

At all times grease, oil, floatable organic materials, and settleable solids should be removed from runoff water before it enters the dry well. These materials can take up storage capacity in addition to reducing infiltration rates. Screens should be placed at the top of the roof leader to prevent leaves from entering the dry well.

When a runoff filtering system or structure is included in the design, the maintenance requirements shall be included.

Outflow Structures

Other than overflow provisions outflow structures are generally not used with infiltration systems. The use of a positive drain or discharge pipe from such structures converts the infiltration structure into a detention structure, unless the positive drain is located such that a volume of storage is provided below the positive drain invert.

In all cases, however, the overland flow path of surface runoff exceeding the capacity of the well shall be evaluated to preclude the development of uncontrolled, erosive concentrated flow. An overflow system leading to a stabilized channel or watercourse including measures to provide non-erosive flow conditions along its length and at the outfall shall be provided. An overflow orifice shall be installed in the inflow pipe above the dry well surface area to allow drainage in extreme events as shown in Figure 3-6.

Seepage Analysis and Control

A foundation analysis shall be made to determine any possible adverse effects of seepage zones on nearby building foundations, roads, parking lots, and other structures. This is particularly important on a steeply sloping site. Developments on sloping sites often require the use of extensive cut and fill operations. The use of dry wells on large or steeply sloping fill sites is not recommended. Fill areas can be very susceptible to slope failure due to slippage along the interface of the in-situ and fill material. This condition could be further aggravated if the fill material is saturated by using infiltration practices. The methods for seepage analysis and estimation of infiltration rates using Darcy's law and flow nets can be used to conduct the seepage analysis.

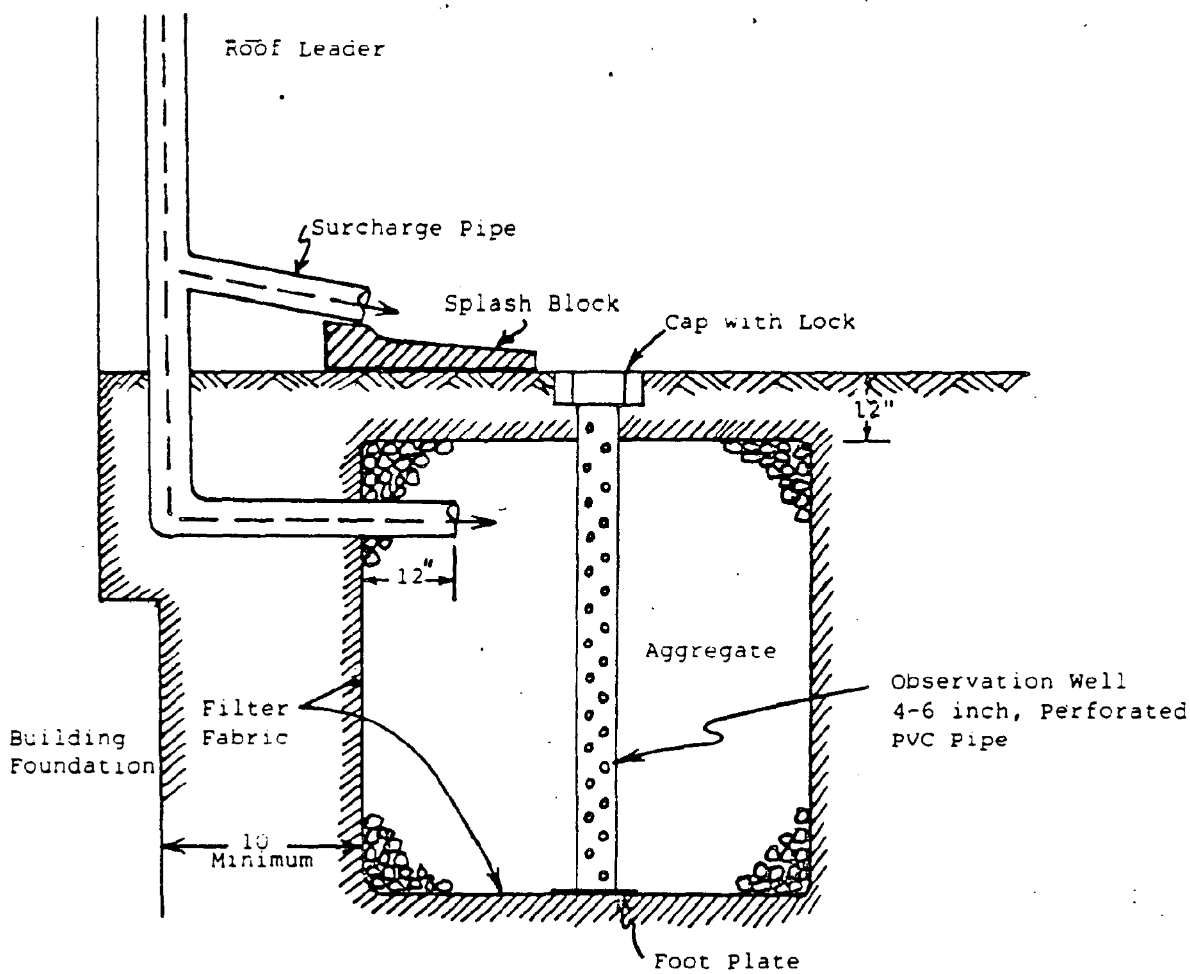
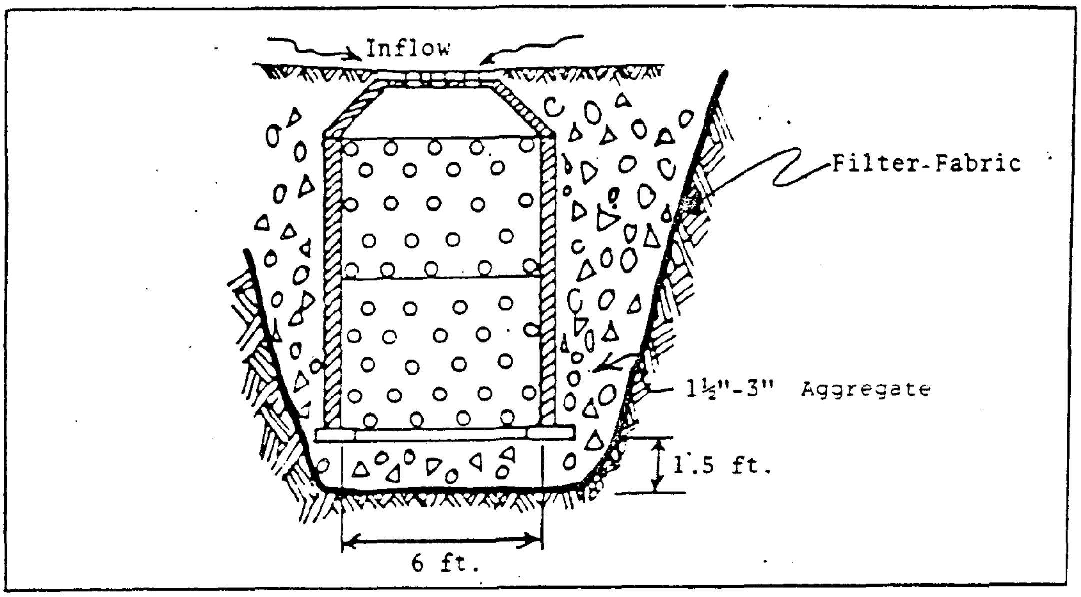
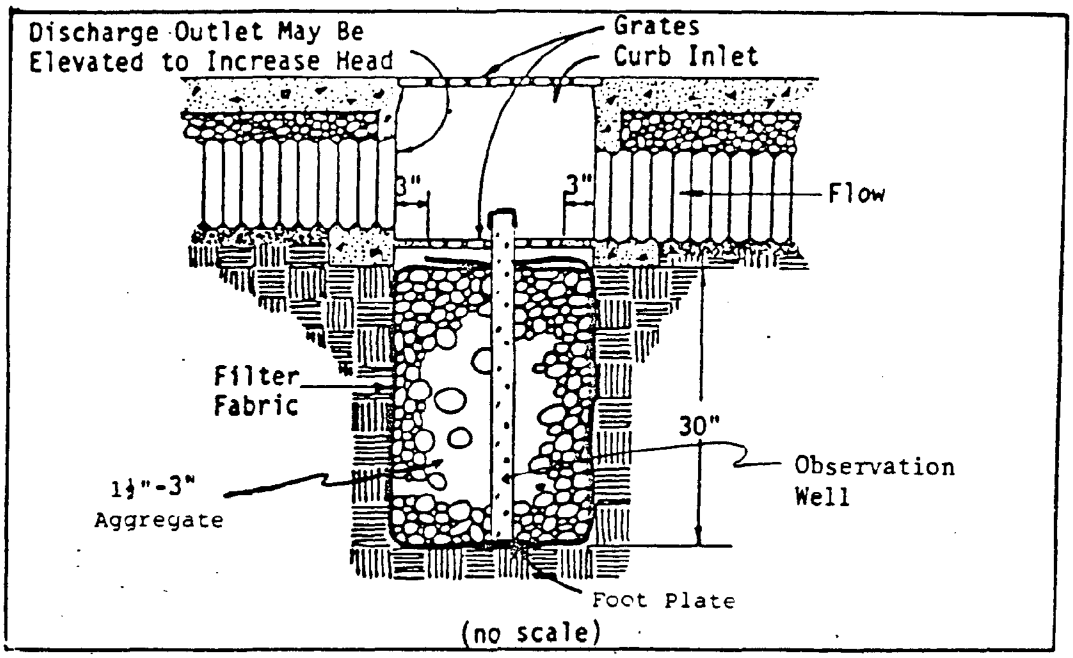


Figure 3-6. Typical Dry Well Cross Section



(a)

Source: Modified from Sullivan (1981)



Source: COG (1979)

Figure 3-7. Examples of Storm Drain Catch Basins Used as Dry Wells

When dry wells are used in residential areas, special care must be taken to prevent seepage from the dry wells creating wet basements. Dry wells should be located at least a distance of four times the well depth down gradient from foundation walls (minimum of 10 feet).

Hydrologic Design Methods

A recommended hydrologic design method based on SCS procedures is provided in Chapter 4.

Observation Well

An observation well shall be installed in every dry well. The observation well will serve two primary funcitons: 1) it will indicate how quickly the trench dewaters following a storm, and 2) it will provide a method of observing how quickly the well fills up with silt and thus requries maintenance clearout.

The observation well should consist of perforated PVC pipe, 4 inches in diameter. It should be located in the center of the structure and be constructed flush with the ground elevation of the structure as shown in Figure 3-5. The top of the well shall be capped to discourage vandalism and tampering. The depth of the well at the time of installation should be clearly marked on the well cap.

Water Quality

The effectiveness of this practice for runoff and pollution control is dependent upon the size and design of the structure. If a dry well is designed to collect and infiltrate the total volume of runoff for a design storm over a given drainage area, the practice theoretically should be effective for both runoff control and pollution abatement for storms up to and including the design storm. The water quality requirements of the New Jersey State SWM regulations will be satisfied as long as the use of the infiltration practice results in zero runoff from the site under conditions of the water quality design storm.

Construction Specifications

Timing

A dry well shall not be constructed or placed in service until all of the contributing drainage area has been stabilized and approved by the responsible inspector.

Dry Well Preparation

Excavate the dry well to the design dimensions. Excavated materials shall be placed away from the excavated sides to enhance wall stability. Large tree roots shall be trimmed flush with the sides in order to prevent fabric puncturing or tearing during subsequent installation procedures. The side walls of the dry well shall be roughened where sheared and sealed by heavy equipment.

Fabric Laydown

The filter fabric roll shall be cut to the proper width prior to installation. The cut width must include sufficient material to conform to well perimeter irregularities and for a 6-inch minimum top overlap. Place the fabric roll over the well and unroll a sufficient length to allow placement of the fabric down into the well. Stones or other anchoring objects should be placed on the fabric at the edge of the well to keep the lined well open during windy periods. When overlaps are required between rolls, the upstream roll shall lap a minimum of 2 feet over the downstream roll in order to provide a shingled effect. The overlap ensures fabric continuity or the fabric conforms to the excavation surface during aggregate placement and compaction.

Aggregate Placement and Compaction

Drainage aggregate shall be placed in lifts and compacted using plate compactors. As a rule of thumb, a maximum loose lift thickness of 12 inches is recommended. The compaction process ensures fabric conformity to the excavation sides, thereby reducing the potential for soil piping and fabric clogging.

Overlapping and Covering

Following aggregate placement, the fabric previously weighted by stones should be folded over the aggregate to form a 6" minimum longitudinal lap. The desired fill soil should be placed over the lap at sufficient intervals to maintain the lap during subsequent backfilling.

Contamination

Care shall be exercised to prevent natural or fill soils from intermixing with the drainage aggregate. All contaminated aggregate shall be removed and replaced with uncontaminated aggregate.

Voids Behind Fabric

Voids can be created between the fabric and excavation sides and should be avoided. Removing boulders or other obstacles from the trench walls is one source of such voids. Natural soils should be placed in these voids at the most convenient time during construction to ensure fabric conformity to the excavation sides. Soil piping, fabric clogging, and possible surface subsidence will be avoided by this remedial process.

Unstable Excavation Sides

Vertically excavated trench walls may be difficult to maintain in areas where the soil moisture is high or where soft cohesive or cohesionless soils predominate. These conditions may require laying back of the side slopes to maintain stability; trapezoidal rather than rectangular cross sections may result.

Foundation Protection

Dry wells 3 or more feet deep shall be located at least 10 feet down gradient from foundation walls.

Observation Well

An observation well, as described earlier and in Figure 3-5, will be provided. The depth of the well, at the time of installation, will be clearly marked on the well cap.

Maintenance

Dry wells shall be designed to minimize maintenance. However, it is recognized that all infiltration facilities are subject to clogging by sediment, oil, grease, grit and other debris. In addition, the performance and longevity of these structures is not well documented. Consequently, a monitoring observation well is required for all infiltration structures.

The observation well should be monitored periodically. For the first year after completion of construction, the well should be monitored on a quarterly basis and after every large storm. It is recommended that a log book be maintained indicating the rate at which the facility dewaters after large storms and the depth of the well for each observation. Once the performance characteristics of the structure have been verified, the monitoring schedule can be reduced to an annual basis, unless the performance data indicate that a more frequent schedule is required.

References

1. Becker, B.C., M.L. Clar, and R.R. Kautzman, Approaches to Stormwater Management, prepared by Hittman Associates, Inc. for the Office of Water Resources Research, USDI, November, 1973.

2. Sullivan, R.J., editor, Urban Stormwater Management, Special Report No. 49, American Public Works Association, Chicago, Illinois, 1981.

3. Anonymous, Controlling Stormwater Runoff in Developing Areas: Selected Best Management Practices, Metropolitan Washington Council of Governments, July, 1979.

4. Design Guidelines for Subsurface Drainage Structures, MIRAFI, Inc., P.O. Box 240967, Charlotte, NC 28224.

3.5. VEGETATED SWALES WITH CHECK DAMS

(VS)

Description

This practice consists of vegetated swales with check dams (see Figure 4-27) to retard or impound concentrated runoff to induce infiltration. This is achieved by directing concentrated flows of surface runoff through vegetated drainage swales or channels where gentle channel slopes and dense vegetative cover provide for a nonerosive flow velocity. The combination of low velocities and vegetative cover also provide an opportunity for nutrients and other pollutants to be filtered or settle out. The check dams, creating small infiltration pools, will generally consist of earthen fill 6 to 24 inches in height.

Applicability

Swales are most applicable in residential and institutional areas of low to moderate density where the percentage of impervious cover is relatively small. This practice requires that subdivision and site designs respect natural drainage patterns in lieu of elaborate storm drain systems.

Swales are usually located in a drainage easement at the side or back of residential lots as shown in Figure 3-8. Swales can also be used along the edge of roadways as a substitute for curb and gutter. This application, which is normally used in rural right-of-way road section is illustrated in Figure 3-9.

Swales with check dams can be used in combination with infiltration trenches when the trench is constructed below the vegetate swales. The pool created by the check dam increases the volume of runoff infiltrated into the trench, while the vegetated swale helps to filter out suspended solids and other runoff pollutants. The infiltration trench in turn will increase the opportunity for runoff to infiltrate into the underlying soil.

Swales with check dams can also be used in conjunction with detention basins. The swales would be designed to control the water quality storm, with overflows controlled by the basin.

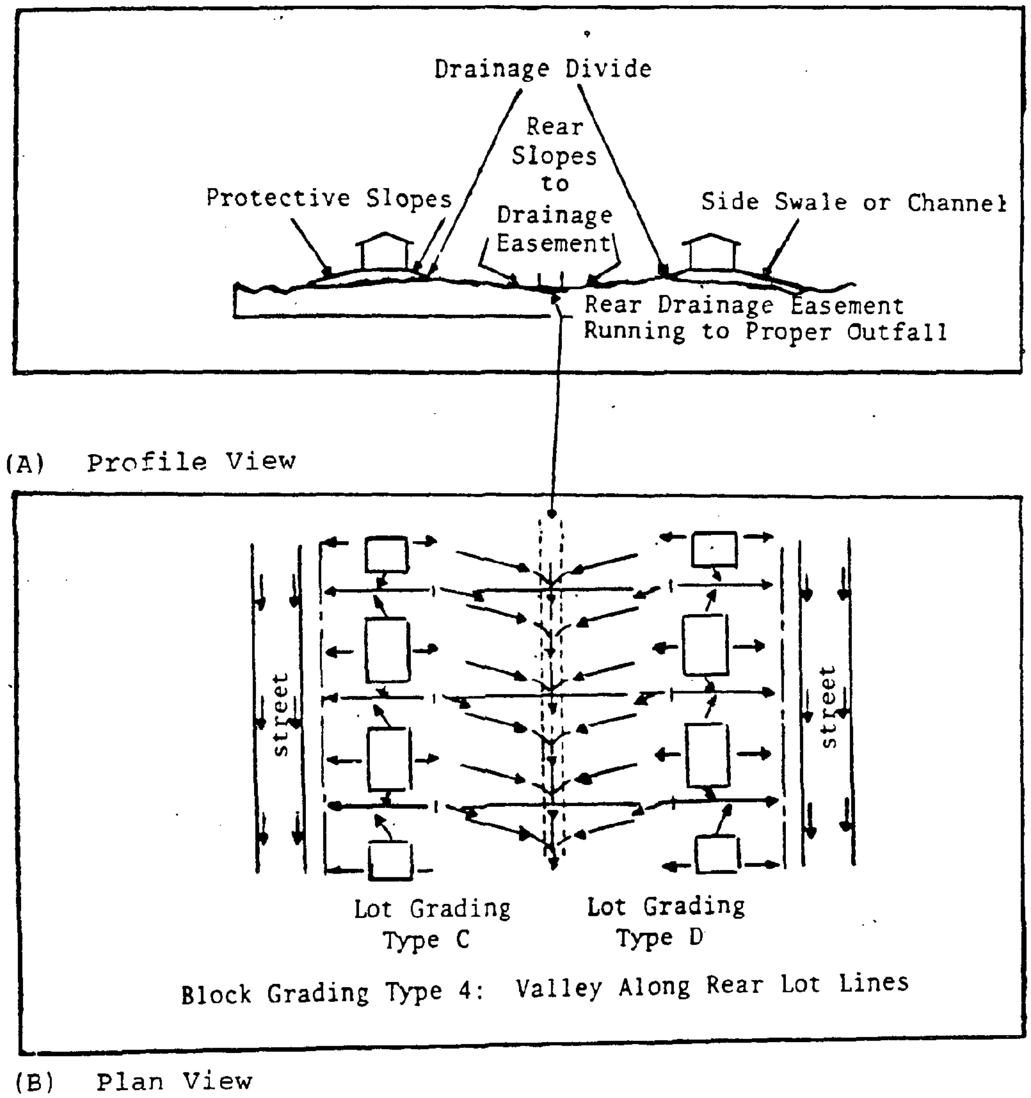


FIGURE 3-8. Typical Lot Grading Plan

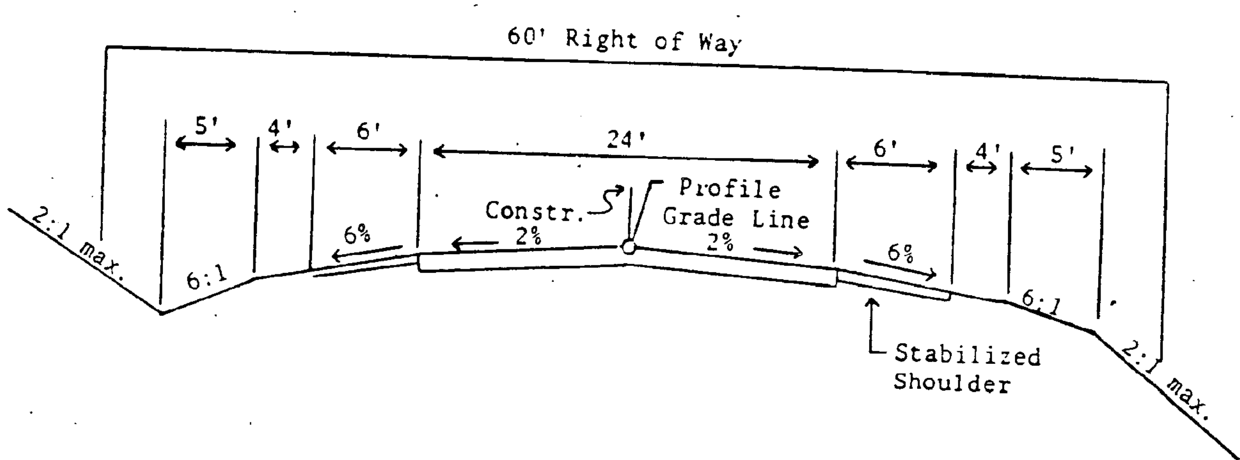


Figure 3-9. Typical Road Cross Section Using Vegetated Swales

Source: RPC 1980

Planning Considerations

Soil Permeability

The permeability or final infiltration rate of the soil as provided in Table 3-1, will limit the utilization of swales for ponding and infiltration of stormwater runoff. The maximum allowable ponding time for swale pond is 24 hours. Table 3-2 relates the ponding time criterion to soil texture and maximum allowable depth of ponding. Based on the data presented in Table 3-2, it is recommended that impoundments not be constructed in swales on soils with f values less than 0.27 inches per hour.

Swale Gradient

The use of small check dams to create impoundments in swales is limited to gradients of 5 percent or less. Although check dams can be constructed on steeper slopes, the volume of runoff stored behind the check dams on steeper slopes will be too small to be of much value. Therefore swales proposed on gradients steeper than 5% shall not be used for stormwater management.

Water Table, Bedrock and Groundwater Considerations

The seasonally high ground water table or bedrock should be at least 1 to 2 feet below the bottom of the swale. Local officials may require greater depths to the groundwater table where proposed developments are expected to have large pollutant loads. It can be observed that one of the advantages of swales is that they allow the use of infiltration methods in permeable soils with relatively high water tables.

Other Considerations

In planning future street drainage systems, officials should weigh heavily the offsite advantages of using vegetated swales instead of curb and gutter systems. The following considerations should also be taken into account:

1. Vegetated swales are generally less expensive to install than curb and gutter systems.

2. Roadside swales keep flow away from the street surface during rainstorms, reducing the potential for hydroplaning of auto tires and wet brake linings.

3. Vegetated swales require more maintenance than curb and gutter systems (mowing, seeding, debris removal, etc.)

4. Roadside swales are subject to damage due to snow plowing and off street parking.

5. Streets with swales may require more right-of-way and are less compatible with sidewalk systems.

6. Roadside swales become less feasible as the number of driveway entrances requiring culverts increases.

7. Roadside swales can be used in conjunction with infiltration trenches and basins to further attenuate runoff and improve its quality.

8. Swales are not usable in all cases where poorly drained soils, extreme slope conditions, or the lack of positive outfalls exists.

Water Quality Control

Vegetative swales with check dames, as with all infiltration practices, can satisfy the water quality requirements of the New Jersey SWM regulations as long as they result in zero runoff from the site under conditions of the water quality design storm.

The diversion of storm water runoff through vegetative swale systems without check dams has been demonstrated to provide for the removal of significant amounts of water bourne pollutants (8,9). Removal is due to filtration, absorption, adsorption, volatilization and other means. Vegetative swales have also been shown to dramatically increase ph of runoff. (9)

Design Criteria

Design Storm

All hydrologic and hydraulic calculations shall be based on the design storm criteria provided in the New Jersey SWM Regulations.

Ponding Time

The maximum allowable ponding time T_p in swales is 24 hours.

Velocity

Swales must be designed so that the velocity of flow expected from the design storm will not exceed the permissible velocity for the type of vegetative lining used. Permissible velocities for grass-lined channels are presented in Table 3-3.

TABLE 3-3. PERMISSIBLE VELOCITIES FOR VELOCITIES FOR VEGETATED CHANNELS*

Cover	Slope 2/ Range (percent)	Permissible Velocity 1/	
		Erosion Resistant Soils (ft. per sec.) K=0.10 - 0.35	Easily Eroded Soils (ft. per sec.) K=0.36 - 0.80
Bermudagrass	0-5 5-10 over 10	8 7 6	6 5 4
Kentucky bluegrass Tall fescue	0-5 5-10 over 10	7 6 5	5 4 3
Grass mixtures Reed canarygrass	2/ 0-5 5-10	5 4	4 3
Lespedeza Sericea Weeping lovegrass Redtop Red fescue	3/ 0-5	3.5	2.5

1/ Use velocities exceeding 5 feet per second only where good cover and proper maintenance can be obtained.

2/ Do not use on slopes steeper than 10 percent except for vegetated side slopes in combination with a stone, concrete, or highly resistant vegetative center section.

3/ Do not use on slopes steeper than 5 percent except for vegetated side slopes in combination with a stone, concrete, or highly resistant vegetative center section.

4/ K is the soil erodibility factor used in the Universal Soil Loss Equation. (See Appendix A1)

Reference Soil Conservation Service Engineering Field Manual Chapter 7, (1969)

Capacity

The swale must have sufficient capacity to pass the peak discharge rate of the design storm above the check dam.

The channel above the check dams shall be designed in accordance with the Manning Formula, unless more detailed design procedures (backwater programs, for example) are required by the approving agency. The Manning Formula is:

$$Q = \frac{1.49}{n} AR^{2/3} S^{1/2}$$

where: Q = flow rate, in cubic feet per second (cfs)

n = roughness coefficient

R = hydraulic radius (feet)

S = hydraulic gradient (ft/ft)

A = cross sectional area (ft^2)

Side Slope

The maximum side slopes shall be governed by the soil condition, type of flow, amount of flow and channel lining. In general, the side slopes shall not exceed the following criteria:

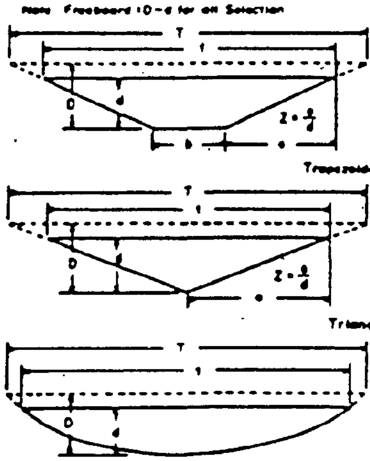
Seeded grasses	3 (horizontal) : 1 (vertical)
Sod	3 : 1
Riprap	2 : 1
Gabion baskets	can be vertical *
9" Gabion mats	1 1/2 : 1

* Special designs to be stepped or placed at 1:6 for heights over 5'.

Cross Sections

Channel cross sections may be vee-shaped, parabolic, or trapezoidal. Properties of typical channel cross-sections are shown in Figure 3-10.

Note: Freeboard = D − d for all Selection



Trapezoidal Cross Section

Triangular Cross Section

Cross-Sectional Area a	Wetted Perimeter, p	Hydraulic Radius R = a/p	Top Width
$bd + Zd^2$	$b + 2d\sqrt{Z^2+1}$	$\frac{bd + Zd^2}{b + 2d\sqrt{Z^2+1}}$	$t = b + 2dZ$ $T = b + 2DZ$
Zd^2	$2d\sqrt{Z^2+1}$	$\frac{Zd}{2\sqrt{Z^2+1}}$ or $\frac{d}{2}$ approx	$t = 2dZ$ $T = \frac{D}{d}t$
$\frac{2}{3}td$	$t + \frac{8d^2}{3t}$	$\frac{t^2d}{1.5t^2 + 4d^2}$ or $\frac{2d}{3}$ approx	$t = \frac{a}{0.67d}$ $T = t\left(\frac{D}{d}\right)^{1/2}$

Figure 3-10. Properties of Typical Channel Cross Sections

(a) Vee-Shaped (Triangular) Ditches. Vee-shaped ditches are generally used where the quantity of water to be handled is relatively small, such as along roadsides. A grass or sod lining will suffice where velocities in the ditch are low. For steeper slopes where high velocities are encountered, a riprap or gabion lining may be necessary.

(b) Parabolic Channels. Parabolic channels are often used where the quantity of water to be handled is larger and where space is available for a wide, shallow channel with low velocity flow. Riprap should be used where higher velocities are expected and where some dissipation of energy (velocity) is desired. Combinations of grass and riprap or gabion mats are also useful where there is continuous low flow in the channel.

(c) Trapezoidal Channels. Trapezoidal channels are often used where the quantity of water to be carried is large and conditions require that it be carried at a relatively high velocity.

A cross-section of a 60-foot-side road right-of-way is shown in Figure 3-9. This cross-section illustrates the common use of center crown sloping at a rate of one-quarter inch per foot toward a swale on each side of the street. Sidewalks can be placed along the swales' banks where hydraulic capacities permit gentle slopes.

In general, swales adjacent to a roadway should have a section with a side slope not steeper than 2:1 (horizontal to vertical) and should preferably have a rounded bottom.

Channel Linings

(a) Grass. The grass type used shall be appropriate for the site conditions, i.e., drainage tolerance, shade tolerance, maintenance requirements, etc. The vegetation should have a dense root system and be water tolerant. Refer to Standards for Soil Erosion and Sediment Control in New Jersey.

(b) Riprap. Riprap shall meet the design criteria set forth in the Riprap Standard in the Standards for Soil Erosion and Sediment Control in New Jersey.

Outlets

Every swale or waterway shall have a stable outlet. This outlet may be another waterway, a stabilized open channel, etc. In all cases, the outlet shall discharge in such a manner as not to cause erosion. Outlets shall be constructed and stabilized before operating the waterway.

Outlet conditions for all channels are very important especially at the transition from a man-made lining such as concrete to a vegetative lining. Appropriate measures shall be taken to dissipate the energy of the flow to prevent scour of the receiving channel. Refer to Outlet Protection Standard in the Standards for Soil Erosion and Sediment Control in New Jersey.

Construction Specifications

The construction specifications provided in the Standards and Specifications for Grassed Waterway of the Standards for Soil Erosion and Sediment Control in New Jersey, shall be used for this practice.

Maintenance

(a) Grass Lined Channels. During the initial establishment of grass-lined channels, any repairs and grass establishment shall be done immediately. After grass has become established, the channel shall be checked periodically to determine if the grass is staying in place. Any mowing of the channel should not damage the grass. Permanent channels shall be mowed periodically to maintain their capacity.

Grassed waterways shall be inspected periodically, especially after large storms, to detemine whether there are erosion problems that need to be controlled, to remove accumulated debris, and to check the condition of the vegetation.

(b) Other Linings. Earth or riprap lined channels shall be checked periodically to ensure that scouring is not occurring at the soil surface or beneath the riprap layer. The channel shall also be checked for slumping of the side slopes and to determine if any stones particularly in channel bends or constrictions have been dislodged by the flow.

(c) Sediment Deposition. If the channel is below a high sediment-producing area, sediment should be trapped using vegetative buffers or sediment traps before it enters the channel. If sediment is deposited in grass-lined channels, it shall be removed promptly to prevent damage to the grass. Sediment deposited in riprap and earth channels shall be removed when it reduces the capacity of the channel.

(d) Homeowner Responsibilities. In residential subdivisions, swale maintenance, such as grass cutting and debris removal is usually the responsibility of the homeowner. More education may be necessary to inform the property owner of these responsibilities and of the need to discourage the off-road parking along swale areas, especially during wet periods when the swale grasses and underlying soils are most vulnerable to damage. Also education is necessary so that the homeowner does not remove the check dams. Such activities can alter the drainage configuration of the swale area and kill the vegetation that stabilizes it and provides natural treatment of runoff.

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3.6. VEGETATIVE FILTER STRIP

(VFS)

Description

A vegetative filter strip or buffer area is an area of vegetative cover through which runoff may flow before it leaves the site or enters a storm water control, such as a detention basin. As the water containing sediment and other pollutants flows through the filter strip, some of the sediment and pollutants are removed by filtering, absorption, and gravity sedimentation as the flow velocity is reduced.

Applicability

Vegetative filter strips can be used by themselves or in conjunction with other stormwater management measures. A vegetative filter can provide the following benefits (Clar, 1981):

1. Serves as an effective method of reducing sediment yield by protecting the soil from rainfall impact energy.

2. Reduces runoff by reducing overland flow velocities, increasing the time of concentration and increasing infiltration.

3. Removes suspended sediment in overland flow by filtering, absorption, and gravity sedimentation as the flow velocity is reduced.

Vegetative filter strips should be considered for use in the following locations.

1. Surrounding storm water management infiltration structures, to reduce the sediment load delivered to the structure.

2. Adjacent to all watercourses (waterways, diversions) and water bodies (streams, ponds and lakes).

3. Along the tops and toes of slopes.

4. Between parking lots and stormwater management structures, where drainage is primarily sheet flow.

5. On certain small projects, such as small commercial sites, offices etc. filter strips can be used to meet the water quality requirements of the New Jersey Storm Water Management Regulations.

Planning Consideration

Almost any stand of vegetative cover will remove some sediment from water flowing through it. These filter strips can occur naturally or be man-made. The type of vegetation used can be very broad. Best performance is associated with dense stands of turf-forming grasses.

The most common, naturally-occurring filter strips are those vegetative stands associated with floodplains or found adjacent to natural swales and watercourses. In some cases, preservation of these areas is all that is required for them to continue to function as filter strips. As these filter strips are expected to perform for several months or more, a top dressing of fertilizer is recommended to improve the stand. In areas where natural vegetation is of poor quality or nonexistent, it is possible to establish a man-made vegetative filter (Albrecht and Barfield, 1981).

Flow

The vegetative filter should be used to control overland sheet flow only. If the filter will be subject to any concentrated flows, such as low points in parking lots or grass areas, then a level spreader or reverse bench should be used to establish sheet flow. When water is discharged directly from a pipe, the filter strip can not be considered an effective water quality control.

Selecting the Type Of Vegetation

The selection of vegetative materials ranges from using existing vegetation to specifying a vegetation mix tailored to suit the characteristics of the site. The New Jersey Standards and Specifications for Soil Erosion and Sediment Control should be used as a guide in selecting the vegetation type.

Slope Characteristics

The effectiveness of vegetative filters as water quality control devices decreases with increasing slope. Their effectiveness has not been established on slopes greater than 17 percent (Albrecht and Barfield, 1981).

Runoff

1. When filter strips are used in treating sediment-laden runoff, the following shall be considered.

2. Good drainage to ensure satisfactory performance.

3. A level spreader at the inlet to ensure uniform distribution of flow.

4. Dry periods between flows to reestablish an aerobic soil profile.

5. An adequate filter area and length of flow to provide the desired treatment.

6. Slopes less than five percent are more effective; steeper slopes require a greater area and length of flow to achieve the same effectiveness.

7. Provisions for mowing and removing undesirable vegetation to maintain the effectiveness of the filter area.

Water Quality

Filter strips have been shown to be effective in removing sediment and pollutant loads in urban storm water runoff. In order to adequately address the water quality requirement of the N.J. SWM regulations, filter strips must be designed to provide at least 75% trap efficiency using Figure 3-13. Also, all runoff must be overland sheet flow only. This can be usually only be accomplished with runoff from small parking lots or roads where depth of flow is less than the height of vegetation. Where catch basins and storm sewers are used to collect and transport runoff, velocities and depths of flow usually preclude the use of filter strips as effective water quality controls.

Design Criteria

Length of Filter Strip

The minimum length of filter strip used in conjunction with all other stormwater management infiltration structures shall be 20 feet.

Additional guidelines to assist the designer in calculating the trap efficiency of an existing vegetative buffer strip, or the length of vegetation filter required to provide a specific trap efficiency are provided below.

Graphical Solution

A solution for computing the sediment trap efficiency of a vegetative buffer strip can be represented graphically (Wong and McCuen, 1982). Figure 3-11 shows the relationship between trap efficiency and the length and slope of the filter strip, as well as the roughness coefficient of the vegetation. The required length of a buffer strip is very sensitive to variation in the trap efficiency as it approaches 100 percent, indicating that a small incremental increase in the trap efficiency requires a considerable addition in the buffer length. The curves also suggest that a significant trap efficiency (up to 75 percent) may be achieved at relatively short buffer lengths. Figure 3-11 assumes a coarse silt material.

The trap efficiency for other soil textures may also be determined using Figure 3-11. The settling velocity of sediment particles manifests the appropriate trap efficiencies that are attainable using filter strips for a particular particle size. In general, the greater the settling velocity, the higher the trap efficiency per length of filter strip. For example, the ratio of the settling velocities for a coarse silt and a fine silt is 4.9. Thus, the filter strip length obtained from Figure 3-11 should be multiplied by this ratio to obtain the filter trip length for a fine silt. This would provide the same trap efficiency indicated on Figure 3-11. The settling velocity ratio of coarse silt to medium silt, fine sands, and medium sands are 1.3, 0.02, and 0.005, respectively (Wong and McCuen, 1982).

Construction Specifications

Site Preparation

1. Install needed erosion and sediment control practices such as silt fences, dikes, and contour ripping, erosion stops, channel liners, sediment traps and sediment basins.

2. If grading is required and topsoil is suitable for use remove and stockpile the topsoil

   Note: Topsoil salvaged from the existing site may often be used but it should meet the same standards as set forth in the specifications. The depth of topsoil to be salvaged shall be 6 inches unless the depth described as a representative profile for that particular soil type as described in the soil survey is less than 6 inches, in which case the lesser depth shall be removed.

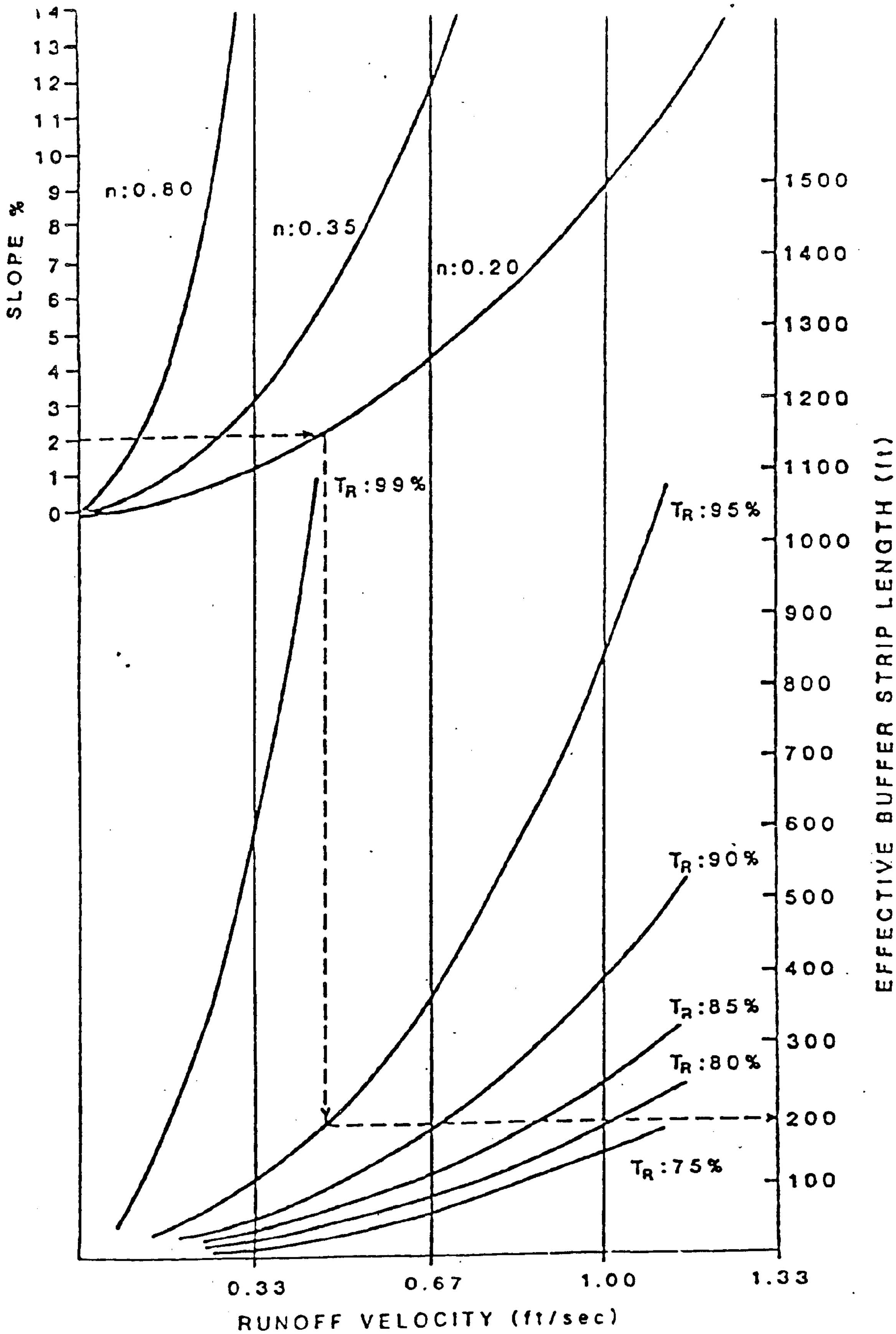

Figure 3-11 Effective Buffer Length Determination for Trap Efficiencies (T_R) of 75, 95, and 99 percent

Source: Wong and McCuen, 1982

3. Grade as needed and feasible to permit the use of conventional equipment for seedbed preparation, seeding, mulch application, anchoring and maintenance.

4. Liming: Where the subsoil is either highly acid or composed of heavy clays, ground dolomite limestone shall be spread at a rate of 2 tons per acre (100 pounds per 1,000 square feet). Lime shall be distributed uniformly over designated area and worked into the soil in conjunction with tillag operations as described in the following procedures.

5. Tilling: After the are to be topsoiled has been brought to grade, and immediately prior to dumping and spreading the top-soil, the subgrade shall be loosened by discing or by scarifying to a depth of at least 3 inches to permit bonding of the topsoil to the subsoil. Pack by passing a bulldozer vertically tracking over the entire surface area of the slope to create horizontal erosion check slots to prevent topsoil from sliding down the slope and rilling.

Soil Preparation and Amendments

1. Materials: Topsoil shall be a loamy sand, sandy loam, loam or silt loam only and in that respective order of preference. It shall not have a mixture of contrasting textured subsoil and contain no more than 5 percent by volume of cinders, stones, slag, coarse fragment, gravel, sticks, roots, trash or other extraneous materials larger than 1-1/2 inches in diameter. Topsoil must be free of plants or plant parts of bermudagrass, quackgrass, Johnson grass, nutsedge, poison ivy, Canada thistle, or others as specified. All topsoil shall be tested by a recognized laboratory for organic matter content, pH and soluble salts. A pH of 6.0 to 7.5 and an organic content of not less than 1.5 percent by weight is required. If pH value is less than 6.0, lime shall be applied and incorporated with the topsoil to adjust the pH to 6.5 or higher. Topsoil containing soluble salts greater than 500 parts per million shall not be used.

   No sod or seed shall be placed on soil which has been treated with soil sterilants or chemicals used for weed control until sufficient time has elapsed to permit dissipation of toxic materials.

   Note: Topsoil substitutes or amendments as approved by a qualified agronomist or soil scientist may be used in lieu of natural topsoil.

2. Grading: The topsoil shall be uniformly distributed and tracked and shall be a minimum compacted depth of 4 inches. Spreading shall be performed in such a manner that sodding or seeding can proceed with a minimum of additional soil preparation and tillage. Any irregularities in the surface resulting from topsoiling or other operation shall be corrected in order to prevent the formation of depressions or water pockets. Topsoil shall not be placed while in a frozen or muddy condition, when the subgrade is excessively wet, or in a condition that may otherwise be detrimental to proper grading and seedbed preparation.

3. Lime and fertilize according to soil tests: Lime and fertilizer needs can be determined by a soil testing laboratory.

4. In lieu of soil tests apply 1,000 pounds 10-10-10 or equivalent per acre if ureaform fertilizer is not used, and 600 pounds of 10-10-10 or equivalent per acre if ureaform fertilizer is used. Apply the lime and fertilizer before seeding and harrow or disc uniformly into the soil to a minimum depth of 3 inches on slopes flatter than 3:1/ On slopes steeper than 3:1 grade, the lime and fertilizer shall be worked in as best as possible. On sloping land, the final harrowing or discing operation should be on the contour wherever feasible. No attempt should be made to drag any disced area to make the soil surface very smooth after discing. When the 600 pounds per acre rate of 10-10-10 fertilizer rate is used, at the time of seeding, apply 400 pounds of a ureaform fertilizer of a grade of a least 30-0-0 per acre.

   Note: The slow release ureaform fertilizer will supply nitrogen over a longer period of time and will result in a healthier grass stand.

<u>Seeding</u>

1. Select a mixture from standards for Soil Erosion and Sediment Control In New Jersey.

2. Apply seed uniformly with a cyclone seeder, drill, cultipacker seeder or hydroseeder (slurry includes seed and fertilizer) on a firm, moist seedbed. Maximum seeding depth should be 1/4 inch on clayey soils and 1/2 inch on sandy soils, when using other than hydroseeder method of application.

Note: If hydroseeding is used and the seed and fertilizer is mixed, they will be mixed on site and the seeding shall be immediae without interruption.

Mulching

Mulch materilas are listed in order of their effectiveness. Mulch mattings are normally only used on critical areas such as waterways or steep slopes.

1. Materials and Amounts

   a. Mulch mattings: Such as jute or excelsior blanket shall be stapled to the surface in waterways and on steep slopes. Lighter materials of paper, plastic and cotton mulch mattings may be used where erosion hazard is not sever. If the area is to be mowed, do not use metal staples.

   b. Straw: Straw shall be unrotted small grain applied at the rate of 1-1/2 to 2 tons per acre, or 70 or 90 (two bales) pounds per 1,000 square foot. Mulch materials shall be relatively free of all kinds of weeds and shall be free of prohibited noxious weeds such as: thistles, Johnsongrass and quackgrass.

      Spread uniformly by hand or mechanically. For uniform distribution of hand spread mulch, divide area into approximately 1,000 square feet section and place 70-90 pounds of mulch in each section.

   c. Wood chips: at the rate of approximately 6 tons per acre or 275 pound per 1,000 square feet may be used when available and when feasible. These are particularly well-suited for utility and road rights-of-way. If wood chips are used, increase the application rate of nitrogen fertilizer by 20 pounds (200 pounds 10-10-10 or 66 pounds 30-0-0).

   d. Wood cellulose fiber: mulch at the rate of 1,500 pound per acre or 35 pounds per 1,000 square foot may be applied by hydroseeding.

2. Mulch anchoring shall be accomplished immediately after mulch placement to minimize loss by wind or water. This may be done by one of the following methods, (listed by preference) depending upon size of area, erosion hazard, and cost. On slopping land, practice No. 1 below, should be done on the contour whenever possible. Contouring of all operations applies to all straw and to wood chip practices

TABLE 3.4
SOILS, SEED MIXTURES AND DATES
FOR PERMANENT SEEDINGS

SOILS	MIXTURES		RATE Lbs./Ac.	Lbs./1000 Sq. Ft.	OPTIMUM SEEDING DATES	
					North Jersey	South Jersey
A. Droughty (sands, shallow, steep, shaly, gravelly)	A-1	KY-31 Tall fescue Crownvetch Creeping red fescue Chewings red fescue	15 10 10 10	3/8 1/4 1/4 1/4	Before 5/1 8/1-9/1	Before 4/15 8/10-9/10
	A-2	Weeping lovegrass Sericea lespedeza Chewings red fescue Creeping red fescue	2 20 10 10	1/16 1/2 1/4 1/4	3/1-7/1	3/1-7/1
	A-3	Midland bermudagrass	8 bu. 2-3' centers		--	4/15-7/15
	A-4	Other hybrid bermuda-grass	20 bu. 12" centers		--	4/15-7/15
	A-5	Perennial ryegrass Chewings red fescue Creeping red fescue	20 15 15	1/2 3/8 3/8	Before 5/1 8/1-10/15	Before 4/15 8/15-11/1
B. Well drained; moderately well drained	Mixtures A-1 thru A-5 are applicable					
	B-1	Ky-31 tall fescue Chewings red fescue Creeping red fescue	30 15 15	3/4 3/8 3/8	Before 6/1 8/1-10/15	Before 5/1 8/15-11/1
	B-2	Ky-31 tall fescue or Creeping red fescue Chewings red fescue Birdsfoot trefoil	15 15 15 10	3/8 3/8 3/8 1/4	Before 6/1 8/1-9/1	-- --
	B-3	Perennial ryegrass Chewings red fescue Creeping red fescue Kentucky bluegrass	20 15 15 15	1/2 3/8 3/8 3/8	Before 6/1 8/1-10/15	Before 5/1 8/15-11/1

d. Wood Cellulose Fiber: Wood cellulose fiber may be used for anchoring straw. The fiber binder shall be applied at a net dry weight of 750 pounds/acre. The wood cellulose fiber shall be mixed with water and the mixture shall contain a maximum of 50 pounds of wood cellulose fiber per 100 gallons.

e. Pet and Twine: drive 8- to 10-inch wooden pegs to within 2 to 3 inches of the soil surface every 4 feet in all directions. Stakes may be driven before or after applying mulch. Secure mulch to soil surface by stretching twine between pegs in a criss-cross within a square pattern. Secure twine around each peg with two or more complete turns.

Note: All names given above are registered trade names. This does not constitute a recommendation of these products to the exclusion of other products.

Irrigation

If soil moisture is deficient, supply new seedings with adequate water for plant growth until they are firmly established, if feasible. This is especially true when seedings are made late in the planting season, in abnormally dry or hot seasons, or on adverse sites.

Maintenance

Maintenance is a vital factor in maintaining an adequate vegetative erosion control cover. See Standards for Soil Erosion and Sediment Control in New Jersey to obtain the maintenance fertilization program for permanent seedings.

a. Irrigation: If soil moisture becomes deficient, irrigate to prevent loss of stand of protective vegetation, if feasible.

b. Repairs: Inspect all seeded areas for failures and make necessary repairs, replacements, and reseedings within the planting season, if possible.

   1. If stand is inadequate for erosion control, overseed and fertilize using half of the rates originally applied.

   2. If stand is over 60 percent damaged, reestablish following original lime, fertilizer, seedbed preparation and seeding recommendations.

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CHAPTER 4

HYDROLOGIC DESIGN METHODS, INFILTRATION AND VOLUME CONTROLS

INTRODUCTION

Design procedures are presented in this chapter for four volume control stormwater management methods: infiltration basins, infiltration trenches, dry wells, and vegetated swales with check dams.

As used herein, an infiltration basin is an open, surface storage area that has no primary hydraulic outlet. Outflow is assumed to be infiltration through the underlying soil and thru an emergency spillway.

The use of these methods should be considered in the context of general limitations outlined in Chapter 3.

Infiltration basins can be used in conjunction with detention basins. This would usually be accomplished by installing a discharge structure with outlets raised. The volume provided below the outlet should not exceed the infiltration capacity of the basin. For dual purpose designs, this volume should be equal to the runoff from the water quality design storm.

Infiltration trenches and dry wells depend on subsurface storage; these two methods differ on the mechanism for input. Input to an infiltration trench is through a highly porous stone medium that overlays the trench or an inlet. Input to a dry well is through both infiltration and pipe inflow.

Estimating the Runoff Depth Required for Control

The methods proposed herein are based on the control of discharge rates either by storing the runoff depth due to changes in land use or by reducing both the contributing area and the runoff depth. New Jersey storm water management policy requires the peak discharge for selected return periods to be not increased after development. However, if the increase in peak discharge cannot be managed, the infiltration practice can be designed to capture the water quality storm runoff. Capturing the water quality design storm runoff will satisfy the water quality requirements of the New Jersey storm water management regulations.

Unlike rate controls, such as detention basins, volume controls do not require detailed hydrograph routings. Infiltration practices can be designed using the Soil Conservation Service Graphical Method of determining peak discharge.The before development peak discharge (q_b) can be determined by:

$$q_b = q_{ub} \, AQ_b \qquad (4\text{-}1)$$

in which q_{ub} is the unit peak discharge, in cubic feet per second per square mile per inch of runoff (csm/in.), from Figure 4-1 based on the before development time of concentration (t_{cb}) in hours, Q_b is the before development depth of runoff in inches, and A is the drainage area in square miles. Using a subscript "a" to indicate "after development", the after development peak discharge (q_a) is given by:

$$q_a = q_{ua} \, AQ_a \qquad (4\text{-}2)$$

While the total drainage area (A) will remain constant, both the unit peak discharge (q_u) and the runoff depth (Q) will probably be greater for the after development conditions. If development causes a decrease in the time of concentration, then the unit peak discharge will increase. Similarly, an increase in the percent of imperviousness will cause an increase in the volume of runoff. If the storm water management policy requires q_a to equal q_b, then the policy could be met if a difference in depth of runoff Q was controlled; this is determined as follows:

$$q_{ua} \, A(Q_a - \quad Q) = q_{ub} \, AQ_b \qquad (4\text{-}3)$$

Therefore, solving for Q yields:

$$Q = Q_a - (q_{ub}/q_{ua})Q_b \qquad (4\text{-}4)$$

If there is no change in t_c, then (q_{ub}/q_{ua}) equals 1.0, and $Q = Q_a - Q_b$. Since the development will usually decrease the time of concentration, q_{ub} will usually be less than q_{ua} and Q will be greater than the difference in the runoff depths ($Q_a - Q_b$).

In addition to controlling discharge rates by adjustments in the runoff depth, it is also feasible to limit discharge rates by reducing both the areas and depth of the after development runoff. Specifically, if development causes an increase in both q_u and Q, then the rate of runoff can be reduced by decreasing A and Q_a in Equation 4-2. If a part of the watershed, which will be denoted by A_c is modified so that it does not contribute runoff to the watershed outlet, then it is possible for the after development peak discharge to equal the before

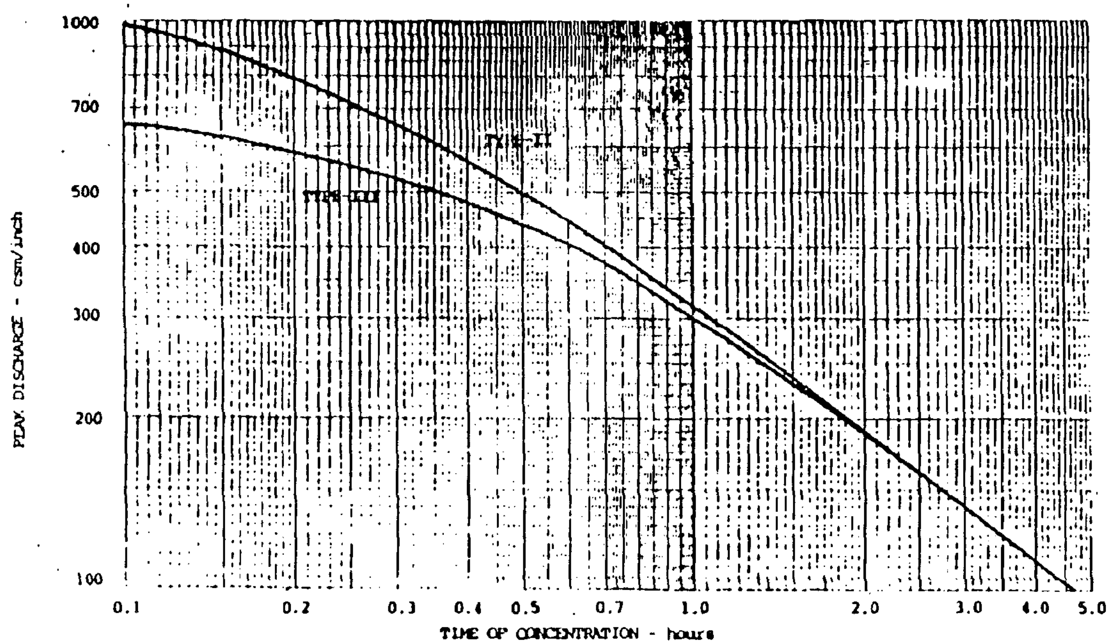


Figure 4-1 Peak discharge in csm per inch of runoff versus time of concentration(Tc) for 24-hour, type II and type III storm distribution.

peak discharge. Using Equations 4-1 and 4-2, the drainage area section A_c would be given by:

$$q_{ua}(A - A_c)Q_a = q_{ub}\, AQ_b \qquad (4\text{-}5)$$

where Q_a is the total after development runoff depth minus the equivalent runoff volume stored by the infiltration measures (V_w/A). Substituting the value of Q_a in Equation 4-5 and solving for A_c yields:

$$A_c = A\left[1 - \frac{q_{ub}Q_b}{q_{ua}(Q_a - V_w/A)}\right] \qquad (4\text{-}6)$$

If an area A_c is designed to be noncontributing, then the after development peak discharge rate will equal the before development rate even though the depth of runoff increases and/or the time of concentration is reduced.

General Design Situations

There are two general types of situations in which the above methods can be applied. First, one may be interested in the dimensions of the infiltration device that is required to control the increase in peak discharge rates. Second, site conditions may dictate the layout and capacity of the infiltration measures and one might be interested in determining the level of control provided by such a layout. In the latter case, control may not be sufficient and additional control, possibly using surface detention, may be required. It is important to emphasize that the same principles apply to both cases.

Design methodologies were developed for four methods: infiltration basins, infiltration trenches, dry wells, and vegetated swales with check dams. The design procedures are based on either 1) total volume control of the area contributing runoff or 2) partial control of the runoff volume from an area (i.e., the difference in the before and after development runoff depths). For the TR-55 graphical method (Equations 4-1 and 4-2), it is assumed that the peak discharge could be controlled through either Q or A and Q. Dry wells, which provide total area and volume control, store all the runoff incident to the contributing surface area. Infiltration measures that provide partial volume control store the difference in runoff volume necessary to meet the peak control criteria. These include the infiltration basin, infiltration trench, and swale storage. Any of the infiltration measures can control the total contributing area and volume of runoff if the after development design storm depth is stored.

Applicability

The use of infiltration practices to control large volumes of runoff is often impractical. For example, the increased runoff from the 10-year or 100-year storm is often much too large to address through infiltration. The most useful application of the infiltration practices presented is to control the 1-year water quality and 2-year design storms. Infiltration practices that capture all the runoff from the 1-year storm will usually provide sufficient reductions in the 2-year peak to meet the required predeveloped rate of flow. 10-year and 100-year flows will usually require flood control techniques, such as detention basins. The design methodologies presented are based on the Soil Conservation Service Runoff Curve Number procedures. This was done because it is the most widely used and accepted. However, the New Jersey storm water management regulations do not dictate its use in the design of storm water management controls.

Water Quality Design Storm Analysis

In the development of designs for water quality controls, such as infiltration practices or the water quality portion of dual detention basins, the use of the RCN procedure will often underestimate the runoff volume produced by small design storms.

When precipitation (P) is small, producing less than 1.5 inches of runoff, the accuracy of the RCN procedure is affected. When analyzing the New Jersey water quality storm, 1 year 24 hour storm, the loss of accuracy can be critical. This is especially true when the pervious area RCN is below 50. For the purposes of water quality design aspects of storm water basins, the water quality storm analysis should include only impervious areas when the pervious areas RCN is below 50. RCN values under 50 will produce little or no runoff from the small water quality design storm and by weighting the pervious and impervious RCN values the SCS models will underestimate runoff volumes. RCN's under 50 are usually limited to areas with hydrologic soil type "A".

If the weighted RCN method is used to analyze the small rainfall events normally associated with water quality concerns, the volume of runoff provided for in water quality controls may not be sufficient. The following example shows how runoff determination can vary when using a weighted curve number versus the use of impervious areas only.

Example 1

Area of site = 10.0 acres, "A" soils throughout, land use is 50% lawn (pasture in good condition) and 50% impervious. 1-year rainfall = 2.8" Determine 1-year runoff.

Weighted RCN Method

$$RCN\ (wt) = .5(98) + .5(39) = 68.5$$

$$Q = \frac{(P - (0.2S))^2}{P + .08\ (S)} \qquad (4\text{-}7)$$

$$\text{where } S = \frac{1000}{CN} - 10 \qquad (4\text{-}8)$$

S = 4.598, use 4.60; Q = 0.545"

$$\text{Total Volume of Runoff} = \frac{0.545''}{12''/ft} \times 10 \text{ Acres} \times \frac{43560\ ft^2}{Acre}$$

$$= 19{,}783.5\ ft.^3$$

Weighted Runoff Method

Impervious RCN = 98, S = 0.204, Q = 2.57"
Pervious RCN = 39, S= 15.64, Q = 0"

$$\text{Total Volume of Runoff} = \frac{2.57''}{12''/ft} \times 5 \text{ Acres} \times \frac{43560\ ft^2}{Acre}$$

$$= 46{,}645.5\ ft.$$

This example shows that the RCN procedure will underestimate the runoff from a 1-year storm if the weighted runoff method is used. This will always be true when the pervious area RCN is small. To determine whether the pervious area RCN will produce runoff the expression P - 0.2(S) should be used. If P - 0.2 (S) > 0 there will be runoff. The amount is determined by equation 4-7.

If P - 0.2 (S) < 0 there will not be any runoff. P, Q, and S are as defined by the USDA - Soil Conservation Service.

The reason for the discrepancy between the weighted curve number and weighted runoff procedures can be best explained by analyzing what is physically occurring in the catchment and how the model (RCN procedure) simulates the hydrologic response. Specifically, one should review how the hydrologic soil-cover complex models the runoff potential of the land surface when there is a large variation in RCN. Large variations in RCN are typically found when development occurs on A or B soils.

In the example the assumption was made that all the impervious areas are connected. This means rooftop drains lead directly to parking lots, driveways and/or drainage pipes and the rain that falls on an impervious surface has no opportunity for infiltration or transmission losses until it is discharged at the terminus of the onsite drainage conveyance system. With these conditions, a 2.8" rain falling on the pervious areas (lawns etc.) would produce no runoff as the rate of delivery of the precipitation would not exceed the infiltration capacity (field capacity) of the "A" soil with the land cover chosen. In other words, the initial abstraction exceeds the precipitation (or $0.2S > P$) and there will be no rainfall excess. The portion of rain falling on the connected impervious areas would produce an equivalent runoff depth of 2.57" (see example). Assuming transmission losses are negligible, the volume of runoff produced by the rainfall event would equal the depth of runoff times the area of the connected impervious surfaces. This is what is modeled by the "Weighted Runoff Method".

The "Weighted RCN Method" assumes that the runoff from the impervious area and pervious area can be modeled by combining the infiltration/runoff potential of the two different hydrologic soil cover complexes in a weighted fashion. This indicates that if the rainfall fell on a mix of the two areas, the runoff produced can be modeled by using a weighted average of the RCN's. This may be true if the 10 acres were laid out with alternating strips of lawn and asphalt where the runoff from the impervious areas would travel across the lawn areas. This would allow for transmission loses through infiltration.

In essence, the runoff estimated in the example catchment is not being produced by an area with a RCN of 68.5; it is being produced by two separate areas, one with a RCN of 98 and one with a RCN of 39. In this case, with a 2.8" rainfall, only the area with the RCN of 98 produces runoff.

Therefore in the analysis of small rainfall depths, (associated with the States water quality design storm) in areas where there is a large variation in RCN values, only the connected impervious areas should be considered producing runoff.

4.2 DESIGN OF INFILTRATION BASIN

(IB)

An infiltration basin is defined as an open area that has no outlet for direct runoff other than an emergency spillway. The storm runoff, which includes both rainfall that falls on the surface of the basin and direct runoff from the upland area, will either infiltrate or evaporate. Since evaporation is usually negligible during periods of heavy rainfall, the design is to be based on water loss by way of infiltration only.

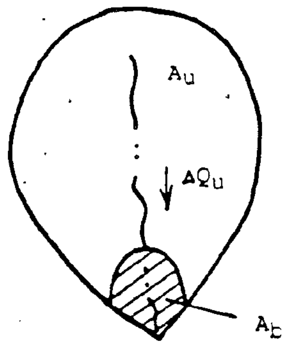
The required size of the basin will depend greatly on the increase in runoff volume from development and the maximum allowable ponding time. A maximum ponding time of 3 days is allowed within the basin. The approving agency and the design engineer may select other specific ponding times provided that the maximum 3 days is not exceeded. If the available area for the basin is smaller than that required to meet the specific peak control criteria, the basin can be designed to capture the first flush of runoff. Capturing the runoff from the water quality design storm will remove many of the waterborne pollutants.

Site Layout

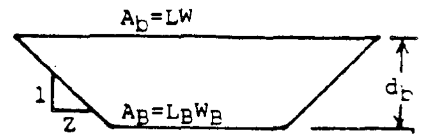
For purposes of definition, the site will consist of two areas: (1) the portion of watershed that contributes direct runoff to the basin, which is denoted as A(u); and (2) the portion of the watershed allocated to the basin, which is denoted as A(b). The subscript u and b are used to indicate the upland and basin drainage areas, respectively. Notations for the site layout are given in Figure 4-2.

Feasibility Test

Before designing an infiltration basin, it is necessary to determine the textural class of soils underlying the basin such that a feasible design is possible. Soils with infiltration rates less than 0.27 inches per hour should not be considered for an infiltration basin. Those soil textural classes that have slow infiltration rates (i.e. less than 0.27 inches per hour) limit the flow of water through the soil. Additionally, the allowable depth of storage may be too shallow to be practical when constructing the structure, based on the maximum ponding time of 3 days. Thus, the suitable textural class of the soil underlying the basin shall be either a silt loam, loam, sandy loam, loamy sand, or sand.

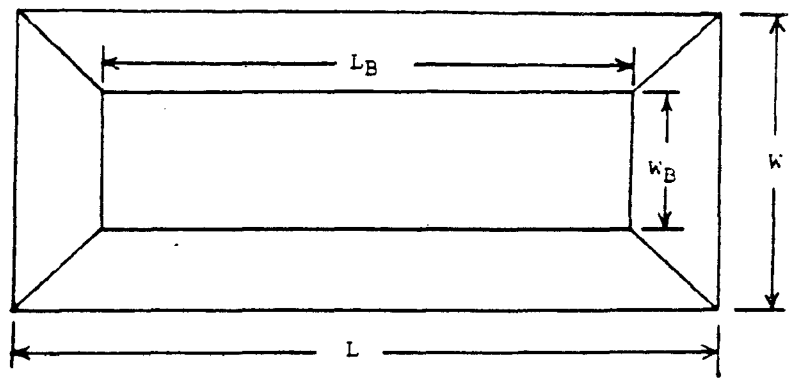


(a) Plan View of Site



(b) Cross Section of Basin

(c) Top View of Basin



Notation

A_u	=	upland drainage area (acres)
Q_u	=	upland runoff depth (ft)
A_b	=	top surface area of basin (ft^2)
A_B	=	bottom surface area of basin (ft^2)
L	=	top length of basin (ft)
L_B	=	bottom length of basin (ft)
W	=	top width of basin (ft)
W_B	=	bottom width of basin (ft)
d_b	=	basin depth (ft)
Z	=	basin side slope ratio

Figure 4-2. Schematic of Infiltration Basin

The design of the infiltration basin is also based upon the maximum depth of the basin d_{max}. The maximum allowable depth shall meet the following criteria:

$$d_{max} = f \times T_p \qquad (4\text{-}9)$$

where f is the final infiltration rate of the basin area in inches per hour, and T_p is the maximum allowable ponding time not to exceed 72 hours. The maximum allowable depths are given in Table 3-2 for selected values of f and T_p.

Design Method

The design method is based on controlling the increased runoff for a specific frequency storm event. The design return period shall be the 1 year frequency storm event. If the discharge associated with the 1 year storm event cannot be managed, a first flush event should be the minimum selected for design.

The basin is sized to accept the runoff volume that enters the basin during the design storm. The design volume of the basin equals the upland runoff volume Q_uA_u to the basin, plus the volume of rain that falls on the surface area of the basin PA_b, minus the exfiltration volume fTA_b out of the bottom of the basin. Based on the SCS hydrograph analysis, the effective basin filling time (T) will generally be less than two hours. The exfiltration volume is small during the two hour period of time to fill the basin. Therefore, the volume of water that enters the soil during the filling of the basin is not significant compared to the much greater upland runoff volume to the basin and may be ignored with little loss of accuracy. The volume of water that must be stored in the basin V_w is defined as:

$$V_w = Q_uA_u + PA_b \qquad (4\text{-}10)$$

where Q_u is the upland runoff depth (ft), A_u is the upland runoff area (ft^2), P is the design rainfall event (ft), and A_b is the basin surface area (ft^2). The upland runoff depth Q_u is determined by:

$$Q_u = \frac{(P - 0.2S)^2}{P + 0.8S} \qquad (4\text{-}11)$$

("P", "S" and "CN" are defined in TR-55)

The volume of rainfall and runoff entering the basin can be defined in terms of the basin geometry. The geometry of the basin will generally be in the shape of an excavated trapezoid with specified side slopes, shown in Figure 4-2. The volume of a trapezoidal shaped basin can be approximated by:

$$V_w = \frac{(LW + L_B W_B)\ d_b}{2} \tag{4-12}$$

where LW is the top surface area of the basin (ft^2), $L_B W_B$ is the bottom surface area of the basin (ft^2), and d_b is the basin depth (ft). The bottom length and width of the basin can be defined in terms of the top length and width as:

$$L_B = L - 2Zd_b$$

$$W_B = W - 2Zd_b \tag{4-13}$$

where Z is a specified side slope ratio (h:v). By setting Equations 4-10 and 4-12 equal and substituting the above relationship for L_B and W_B, the following equation is derived for the basin top length:

$$L = \frac{Q_u A_u + Zd_b^2\ (W - 2Zd_b)}{W(d_b - P) - Zd_b^2} \tag{4-14}$$

The surface dimensions of the basin are determined by selecting a top width (W) and side slope ratio (Z), and solving for the top length (L) from Equation 4-14. Both the top width and length must be greater than $2Zd_b$ such that the bottom dimensions are feasible. All the variables in Equation 4-14 are in units of feet or square feet. The solution to Equation 4-14 is provided in Figures 4-3 through 4-8 for P = 3 inches, Z = 2 or 3, and d_b = 3, 4, 5, 6, 8, or 10 feet. Equation 4-14 may be used to solve for the top length (L) for values not given in Figures 4-3 through 4-8. A maximum side slope ratio of 3:1 for a vegetated basin and 4:1 for a non-vegetated pit is recommended.

In the event that the basin is constructed with an embankment, the basin area and volume will be determined from the natural ground contours. By planimetering the area of the contours above the base of the embankment, a relationship can be developed for depth and surface area to obtain the volume of the basin. The basin volume from the contour data shall be greater than or equal to the volume determined by Equation 4-10.

Design Procedure.

(1) Determine the after development runoff volumes Q_a from after development curve numbers from the SCS TR-55 Manual. Equation 4-11 is used to compute the upland runoff volume Q_u:

$$Q_u = Q_a$$

(2) Compute the maximum allowable basin depth (d_{max}) from the feasibility equation, $d_{max} = f\ T_p$. Select the basin design depth d_b based on the depth that is at least two feet above the seasonal high groundwater table, or the depth less than or equal to d_{max}, whichever results in the smaller depth.

(3) The basin surface area dimensions can be determined from Figures 4-3 through 4-8 or directly by Equation 4-14. If the Figures are used, compute the value $Q_u A_u$ ft^3, select a top width (W) greater than $2Zd_b$, a side slope ratio (Z), and determine the required top length (L). If the variables ($Q_u A_u$, Z, d_b, P, W,) are different than those given in the Figures, use the Figures only as a first trial to find an approximate width and length combination. The exact basin top length (L) is determined from Equation 4-14:

$$L = \frac{Q_u A_u + Zd_b^2\ (W - 2Zd_b)}{W(d_b - P) - Zd_b^2}$$

The basin top length (L) and width (W) must be greater than $2Zd_b$ for a feasible solution. If L and W are not greater than $2Zd_b$, the basin would have no bottom dimensions. In this case, the basin depth d_b shall be reduced for a feasible solution.

The design procedure may also be used for controling an increase in runoff ($Q_a - Q_b$) caused by development. In these cases, the basin would be designed to capture the increased volume of runoff and $Q_u = (Q_a - Q_b)$.

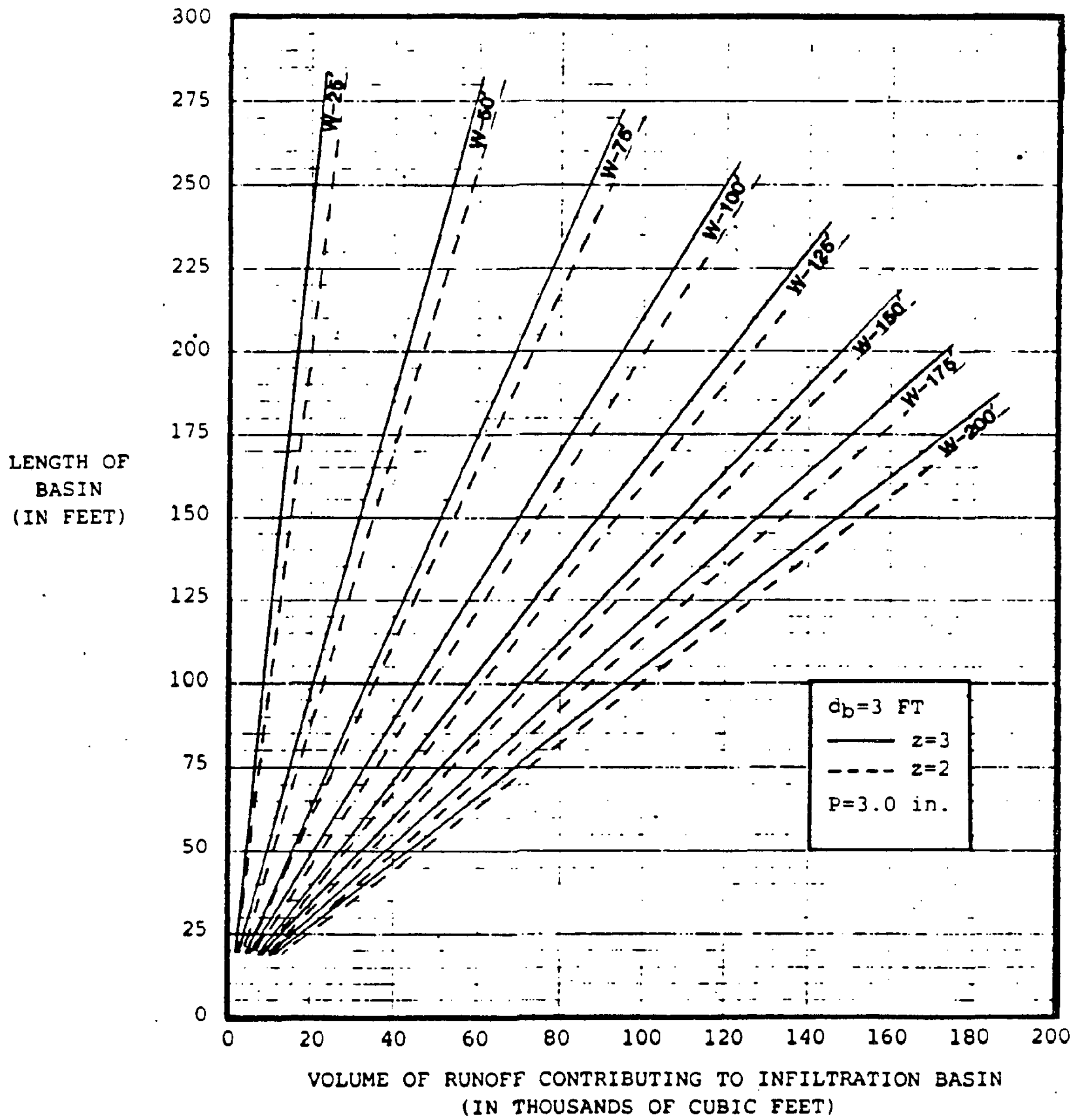


Figure 4-3. Determination of Infiltration Basin Length

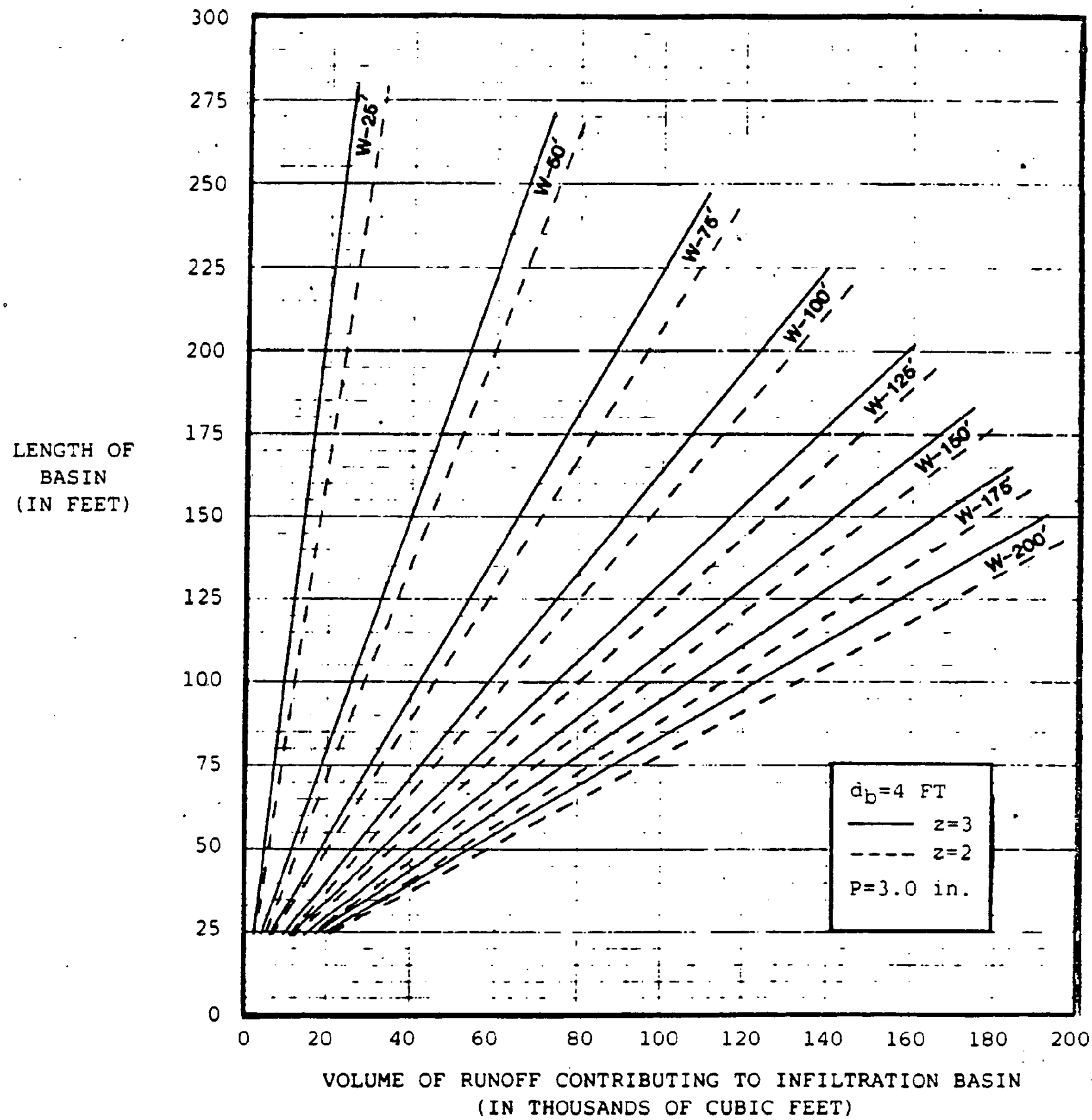


Figure 4-4. Determination of Infiltration Basin Length

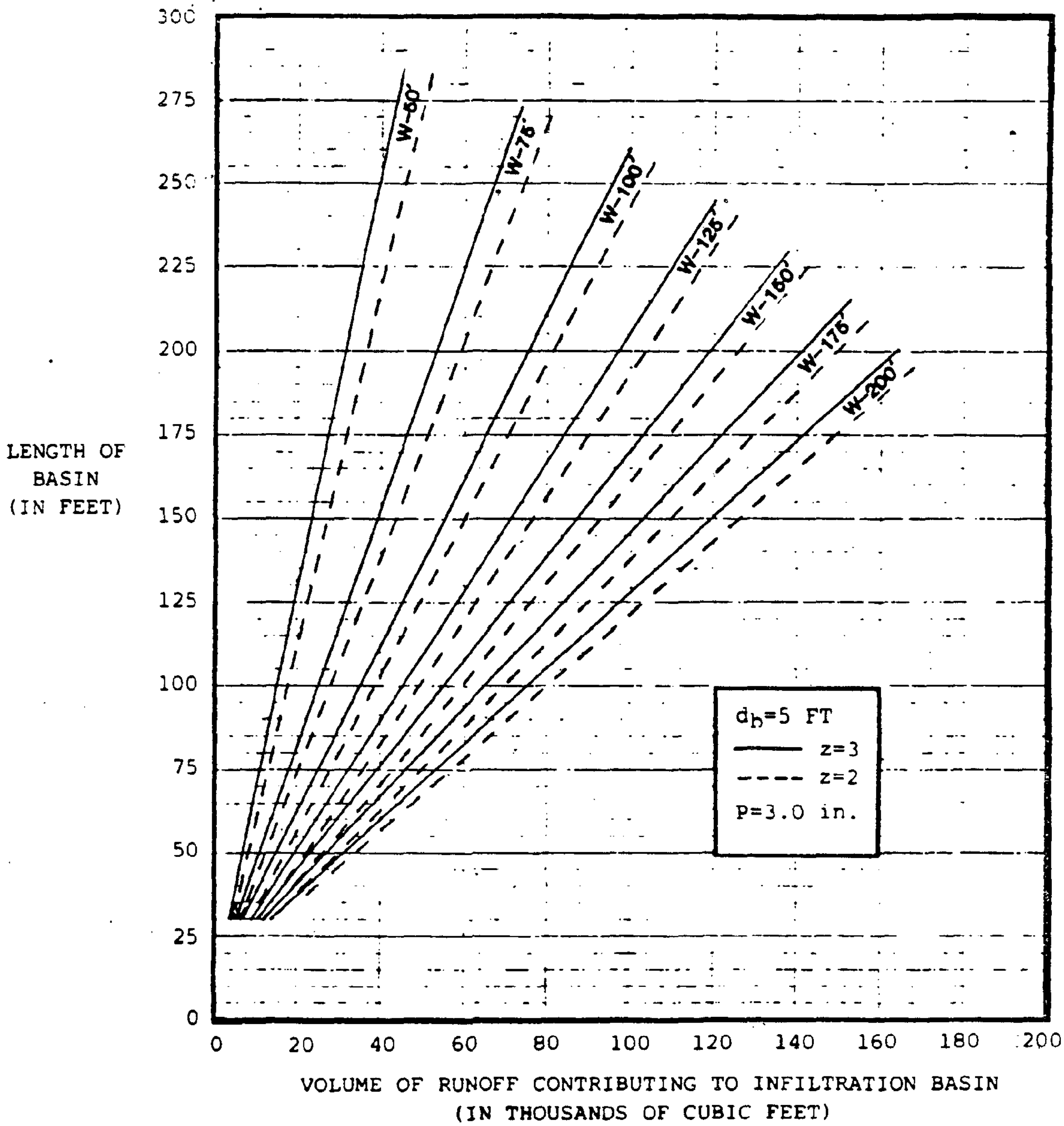


Figure 4-5. Determination of Infiltration Basin Length

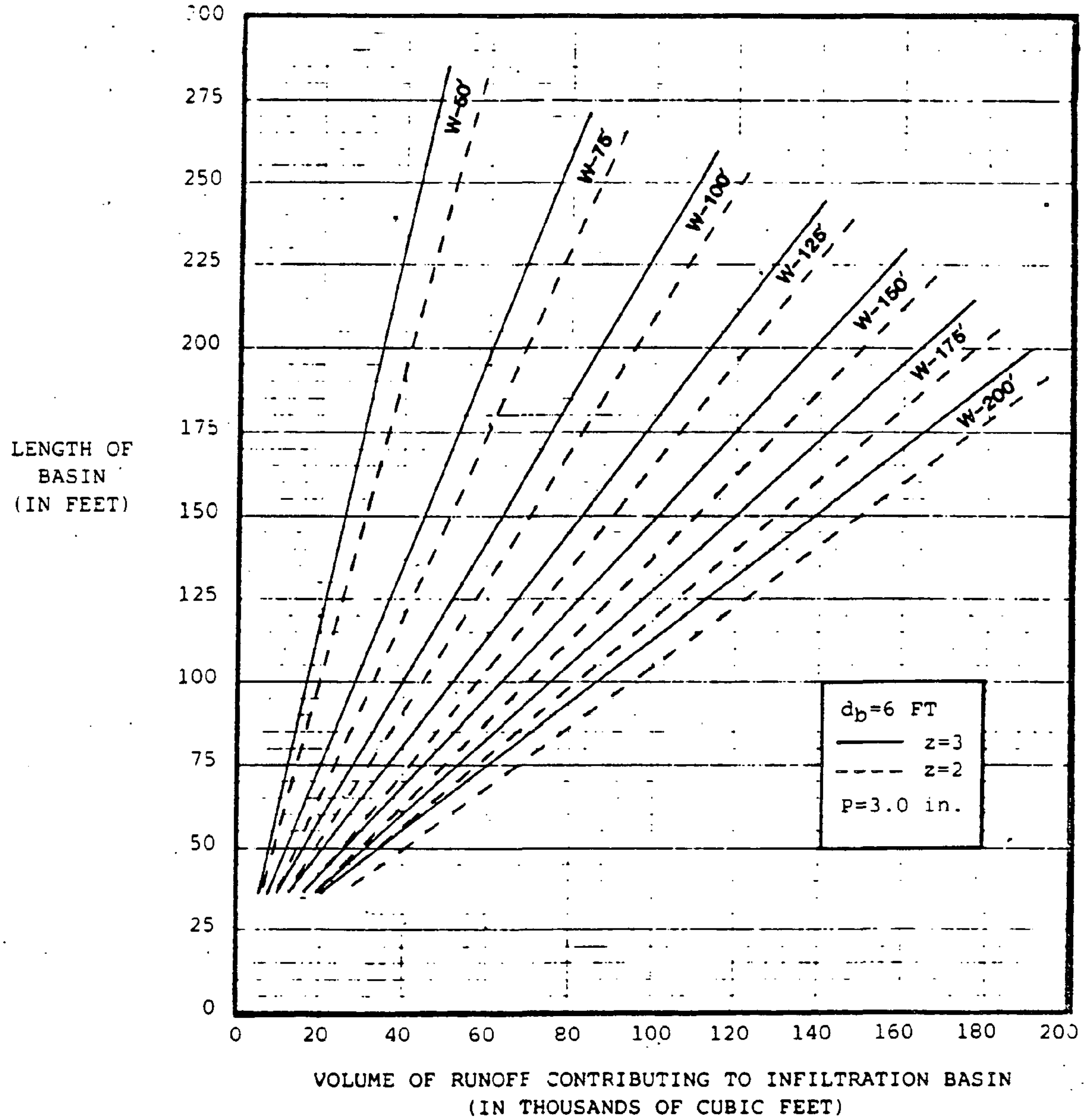


Figure 4-6. Determination of Infiltration Basin Length

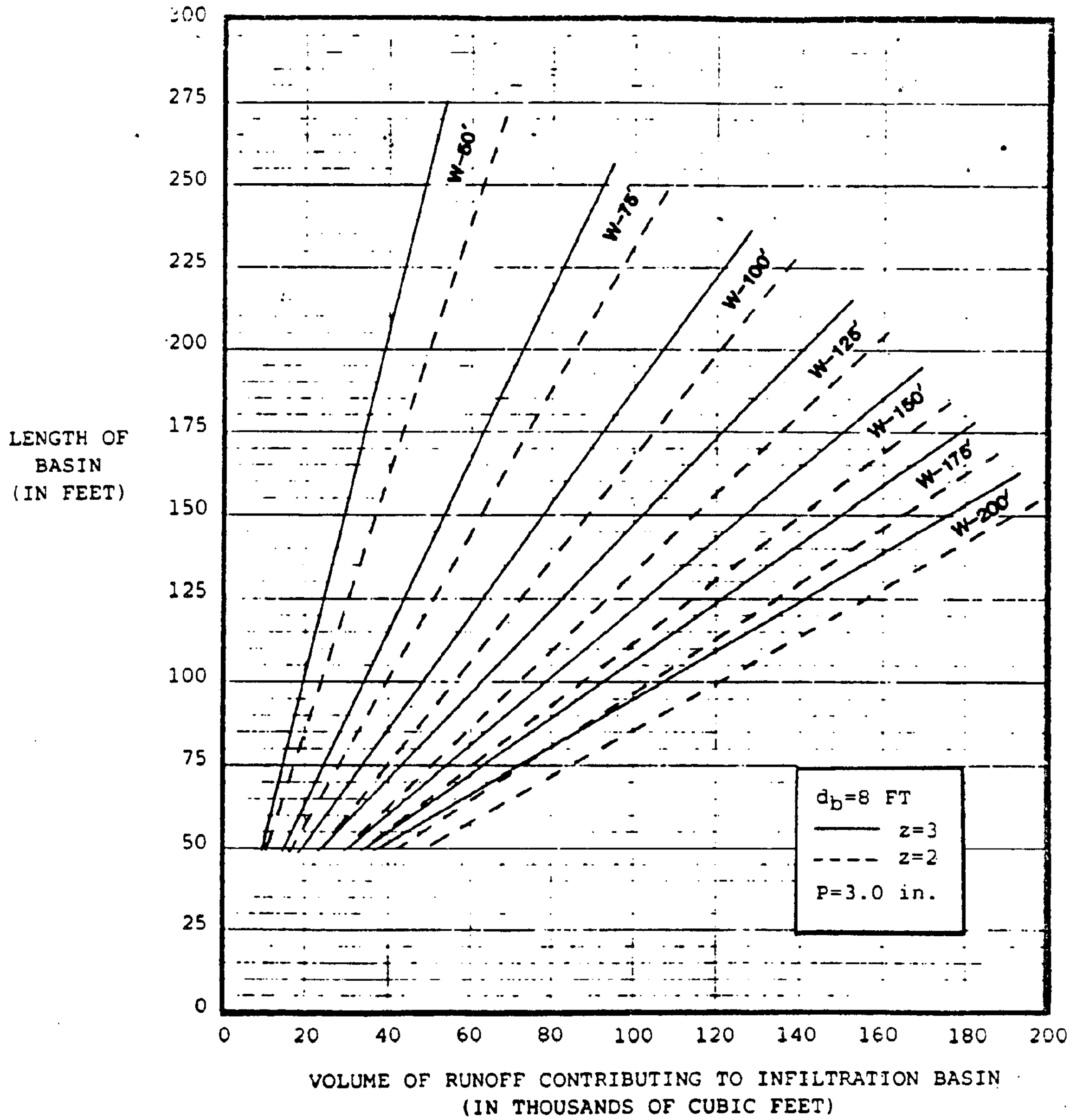


Figure 4-7. Determination of Infiltration Basin Length

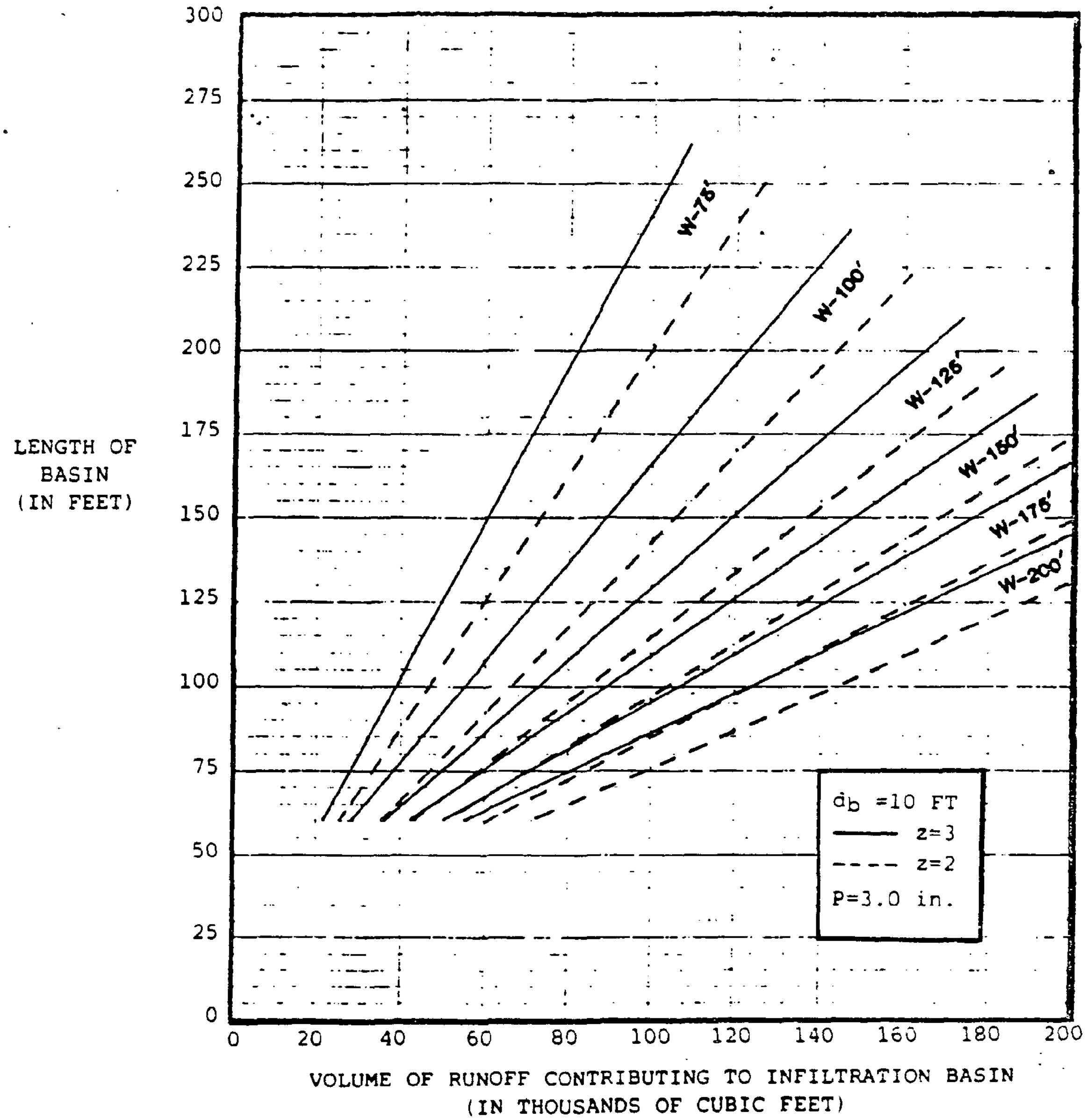


Figure 4-8. Determination of Infiltration Basin Length

4.3. DESIGN OF INFILTRATION TRENCHES

(IT)

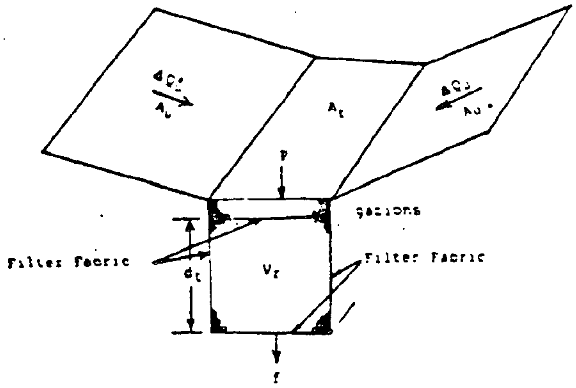
An infiltration trench is defined as a subsurface trench that is used to temporarily store runoff in a stone filled reservoir and exfiltrate the runoff throught the surrounding soil media. The surface of the trench will consist of either a stone covered area or a grass covered area with an inlet, shown in Figure 4-9. If the trench surface area consists entirely of stone, gabion mattresses or large size stone shall be placed on the surface to prevent loss of stone. A grassed trench surface will require an inlet so runoff can effectively enter the stone filled reservoir storage area. The inlet shall be designed to remove heavier sediments to prevent the clogging of the stone void spaces, as shown in Figure 4-10. A filter fabric material will be required at the interface of the soil and reservoir area or below the gabion mattress and around the sides and bottom of the trench. A minimum 20 foot vegetted buffer strip is required around the perimeter of the trench to prevent sediments from entering the trench and thus, increase the life of the trench.

Site Layout

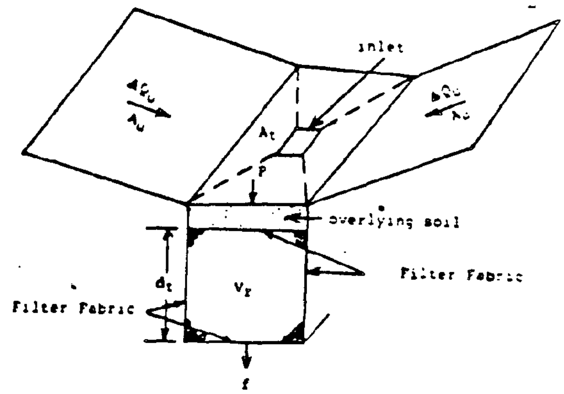
The site for an infiltration trench consists of two areas: (1) the portion of the watershed that contributes runoff directly to the trench, which is denoted as A_u; and (2) the portion of the watershed allocated to the trench which is denoted as A_t. A schematic of an infiltration trench is given in Figure 4-9. The use of an infiltration trench may be in combination with a grassed swale to provide additional storage below the swale.

Feasibility Test

Before designing an infiltration trench, it is necessary to determine the textural class of the soils underlying the trench such that a feasible design is possible. Soils with infiltration rates less than 0.60 inches per hour should not be considered for an infiltration trench. Those soil textural classes that have slow infiltration rates (i.e. less than 0.60 inches per hour) limit the flow of water through the soil. Additionally, the allowable depth of storage may be too shallow to be practical when constructing the structure, based on a maximum storage time of 3 days. Thus, the suitable textural class of the soil underlying the trench should be either a silt loam, loam, sandy loam, loamy sand or



(a) trench with aggregate surface



(b) trench with vegetated surface with inlet

<u>Notation</u>

P	=	rainfall depth (feet)
Q_u	=	upland increase in runoff depth (feet)
A_u	=	upland drainage area (acres)
A_t	=	trench surface area (acres)
d_t	=	trench depth (feet)
f	=	final infiltration rate (feet/hour)
V_r	=	void ratio of stone in trench
T	=	Time during which the trench fills with water. Based on SCS hydrograph analysis, T will generally be less than two hours.

Figure 4-9. Schematic of Infiltration Trench

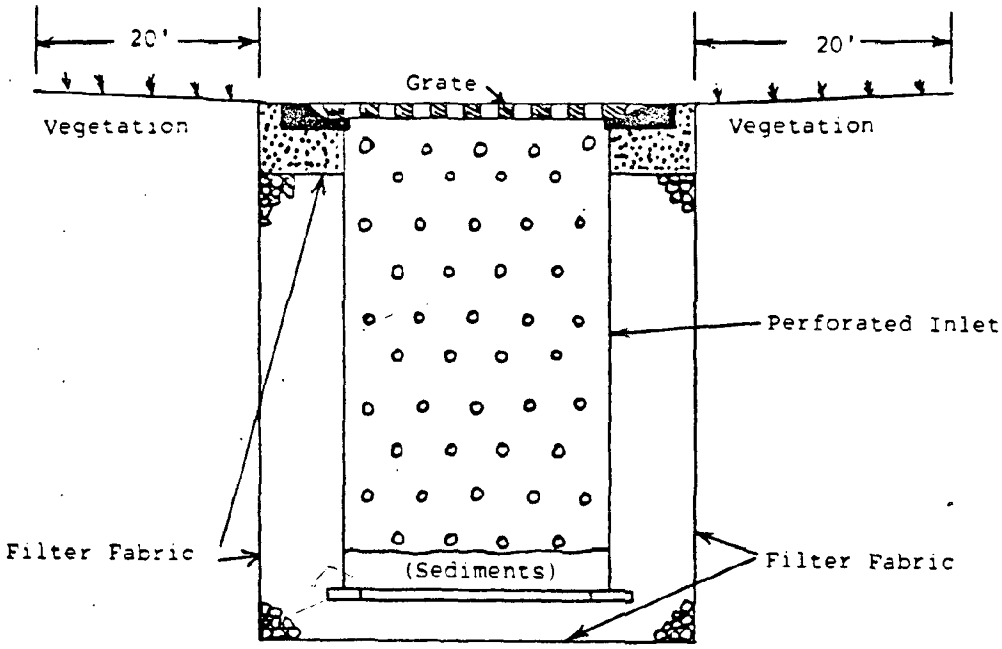


Figure 4-10. Typical Inlet to Infiltration Trench

sand. The soil characteristics shall be investigated and recorded to a depth at least four feet below the bottom of the infiltration trench. The bottom of trench shall be located at least 2 to 4 feet above the seasonal high water table or any impermeable stratum.

The design of an infiltration trench is also based upon the maximum allowable depth of the trench d_{max}. The maximum allowable depth should meet the following criteria:

$$d_{max} = f \times T_s/V_r \qquad (4\text{-}15)$$

where f is the final infiltration rate of the trench area in inches per hour, T_s is the maximum allowable storage time of 72 hours, and V_r is the void ratio of the stone reservoir. The maximum allowable depths are given in Table 3-2 for selected values of f, T_s, and V_r.

Design Method

The design method is based on controlling the runoff for a specific frequency storm event. The design return period shall be the 1 year frequency storm event. If the discharge associated with the 1 year storm event cannot be managed, a first flush event should be the minimum selected for design.

An infiltration trench is designed based on the upland runoff volume contributing to the trench during the design storm. The design volume of the trench equals the upland volume of Q_uA_u contributing to the trench, plus the volume of rain that falls on the surface area of the trench PA_t, minus the exfiltration volume fTA_t out the bottom of the trench. For designs based on the Soil Conservation Service Type III storm, the trench filling time is less than a 2-hour duration. Thus, a duration of 2 hours is used for a value of T. The volume of water exfiltrating during the filling period of the trench may be significant for permeable soils and cannot be ignored. The volume of water that must be stored in the trench V_w is estimated as:

$$V_w = Q_uA_u + PA_t - fTA_t \qquad (4\text{-}16)$$

where units of cubic feet are used to represent the volume. The upland runoff depth Q_u for the upland contributing area A_u is determined as:

$$Q_u = \frac{(P - (0.2S)^2}{P + .08\ (S)} \qquad (4\text{-}17)$$

The volume of rainfall and runoff entering the trench can be defined in terms of the trench geometry. The gross volume of the trench V_t is equal to the ratio of the volume of the water that must be stored V_w to the void ratio V_r of the stone reservoir in the trench; V_t is also equal to the product of the depth d_t and the surface area A_t :

$$V_t = V_w/V_r = d_t A_t \qquad (4\text{-}18)$$

Combining Equations 4-16 and 4-18 yields the following relationship:

$$d_t\ A_t\ V_r = Q_u\ A_u + PA_t - fTA_t \qquad (4\text{-}19)$$

Since both dimensions of the trench d_t and A_t are unkown, Equation 4-19 may be rearranged to determine the area of the trench A_t if the value of d_t were set based on either the location of the water table or the maximum allowable depth of the trench d_{max}:

$$A_t = \frac{Q_u A_u}{(Vrd_t - P + fT)} \qquad (4\text{-}20)$$

Additionally, if the width of a trench was set, Equation 4-20 would yield the required trench length:

$$L_t = \frac{Q_u A_u}{(Vrd_t - P + fT)W_t} \qquad (4\text{-}21)$$

Equations 4-20 and 4-21 are used to develop a graphical relationship for A_t and L_t with values of the other variables. The solution to Equations 4-20 and 4-21 are provided in Figures 4-11 through 4-20 for four different soil types. All variables in Equations 4-20 and 4-21 must be in units of feet.

Design Procedure

1. Determine the after development runoff volume Q_a from the after development curve numbers, from the SCS TR-55 Manual. Equation 4-17 is used to determine the runoff volume as $Q_a = Q_u$.

2. Compute the maximum allowable trench depth d_{max} from the feasibility equation, $d_{max} = f\ T_s/V_r$. Select the trench design depth d_t based on the depth that is at least two feet above the seasonal high groundwater table, or a depth less than or equal to d_{max}, whichever results in the smaller depth.

3. Determine the trench surface area A_t from Figures 4-11 through 4-15, for the particular soil type or compute the trench area directly by Equation 4-20:

$$A_t = \frac{Q_u A_u}{(Vrd_t - P + fT)}$$

If the variables $Q_u A_u$, $V_r d_t$, P, fT) are different than those given in the Figures, use Equation 4-20 for the exact solution.

4. If the width of the trench is set at either 3 or 6 feet, Figures 4-16 through 4-20 may be used to determine the trench length or computed directly from Equation 4-21:

$$L_t = \frac{Q_u A_u}{(Vrd_t - P + fT) W_t}$$

If the variables $Q_u A_u$, $V_r d_t$, P, fT) are different than those given in the Figures, use the Figures only as a first trial to find an approximate width and length combination.

In the event that the side walls of the trench must be sloped for stability during construction, the surface dimensions of the trench area should be based on the following equation:

$$A_t = (L - Zdt)\ (W - Zd_t) \qquad (4\text{-}22)$$

where L and W are the top length and width, and Z is the trench side slope ratio. The design procedure would begin by selecting a top width (W) that is greater than $2Zd_t$ for a specified side slope ratio (Z). The side slope ratio value will depend on the soil type and depth of the trench. The length (L) is then determined as:

$$L = Zd_t + \frac{A_t}{(W - ZD_t)} \qquad (4\text{-}23)$$

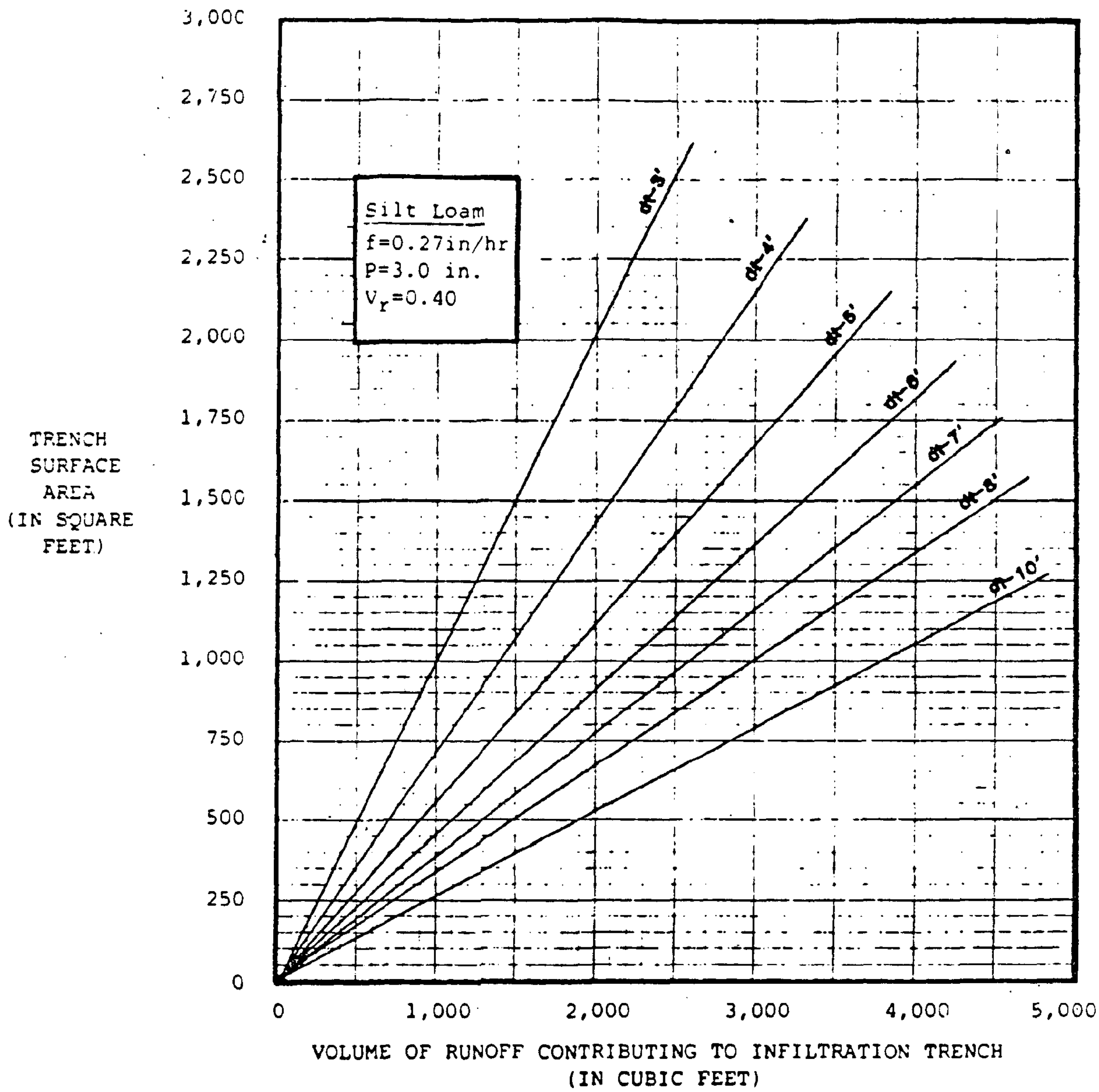


Figure 4-11. Determination of Infiltration Trench Surface Area

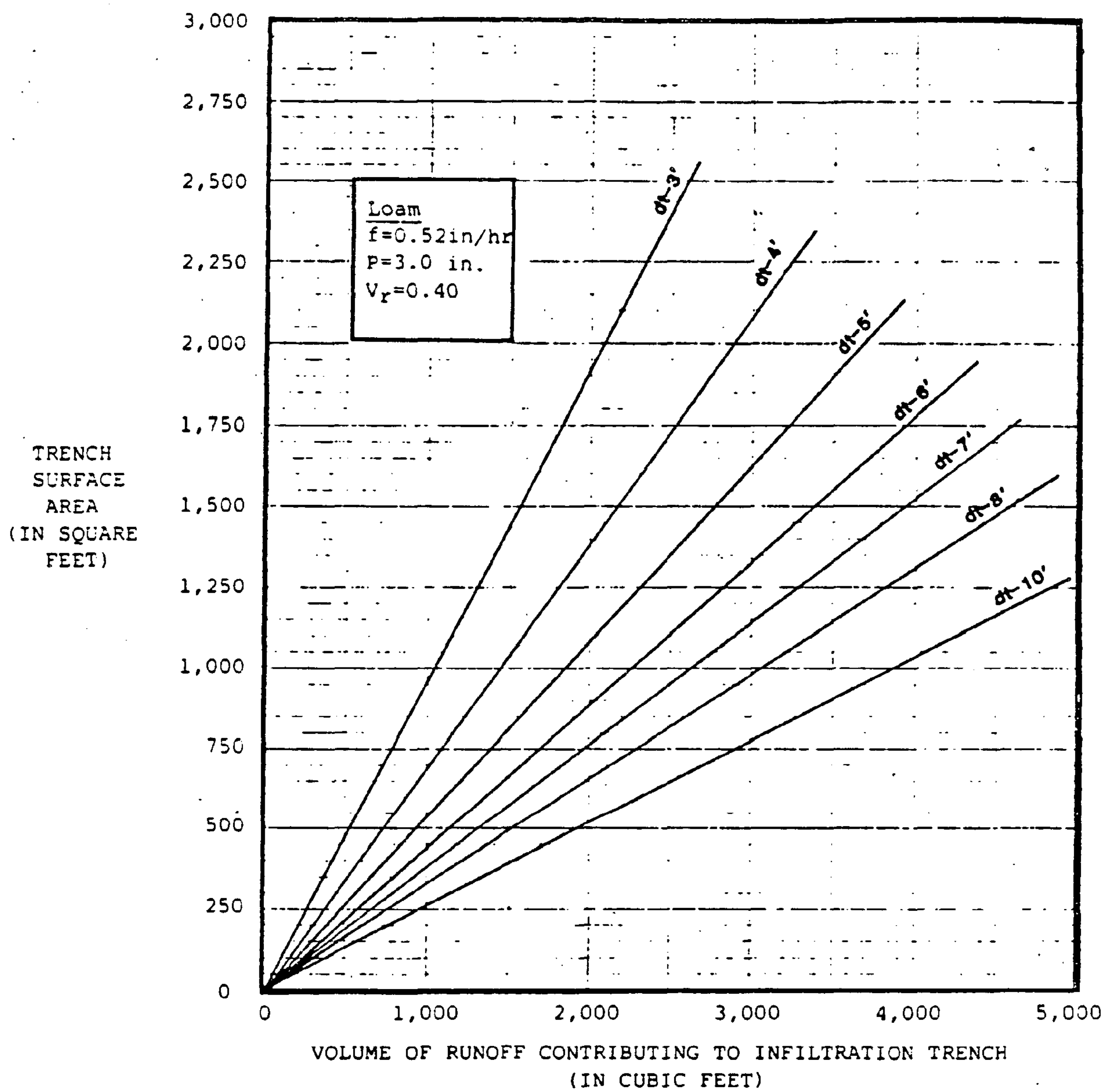


Figure 4-12. Determination of Infiltration Trench Surface Area

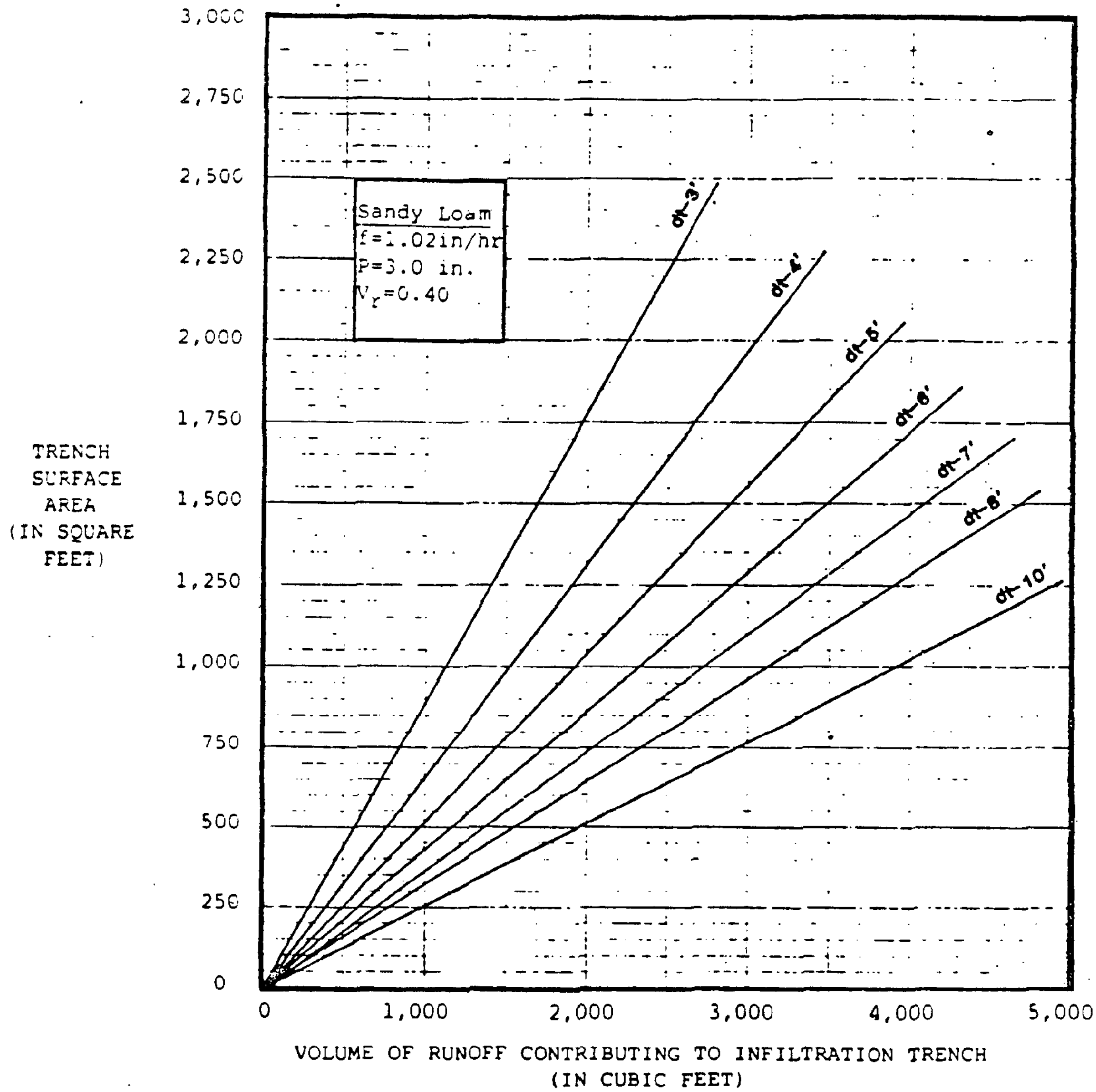


Figure 4-13. Determination of Infiltration Trench Surface Area

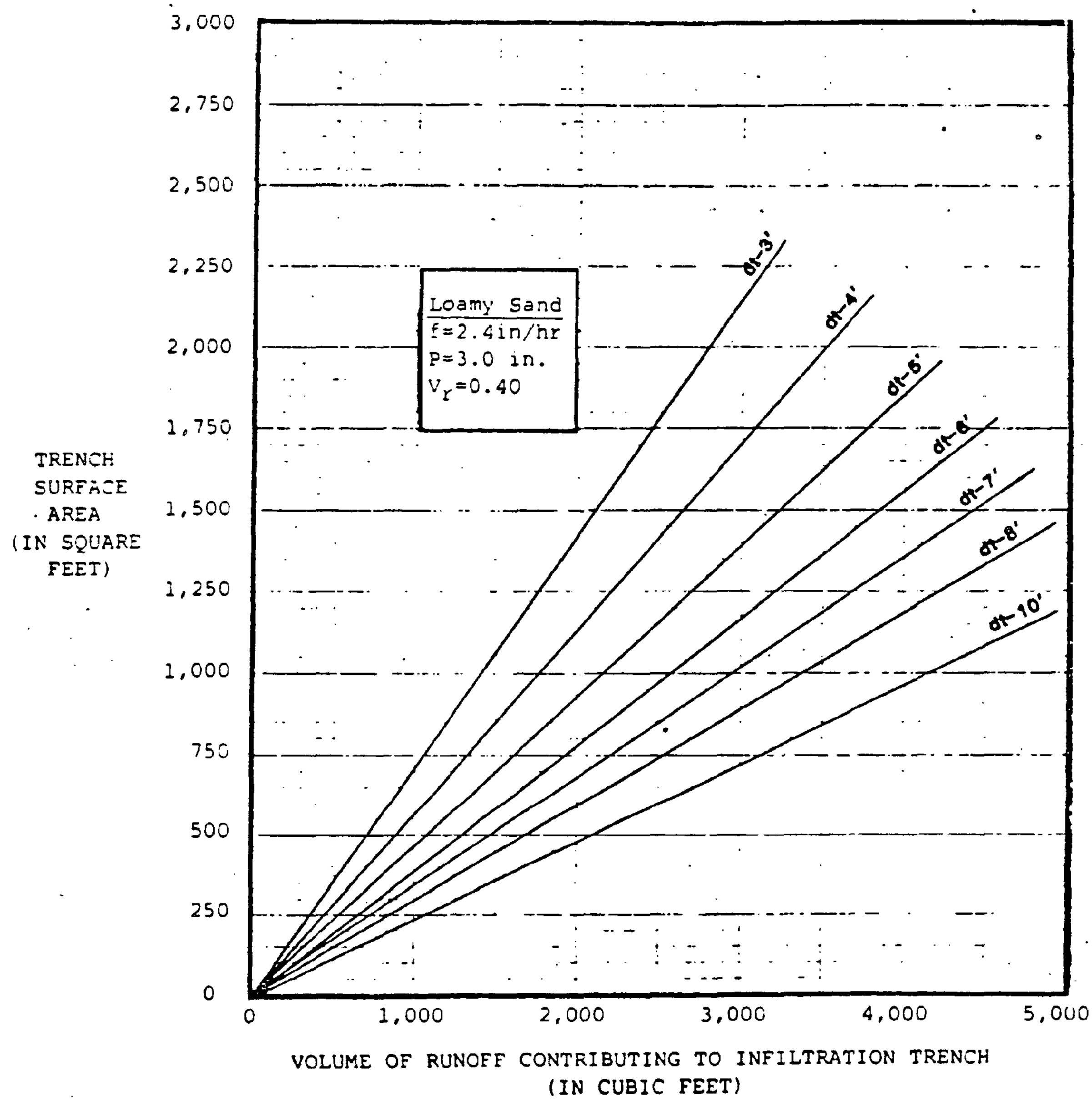


Figure 4-14. Determination of Infiltration Trench Surface Area

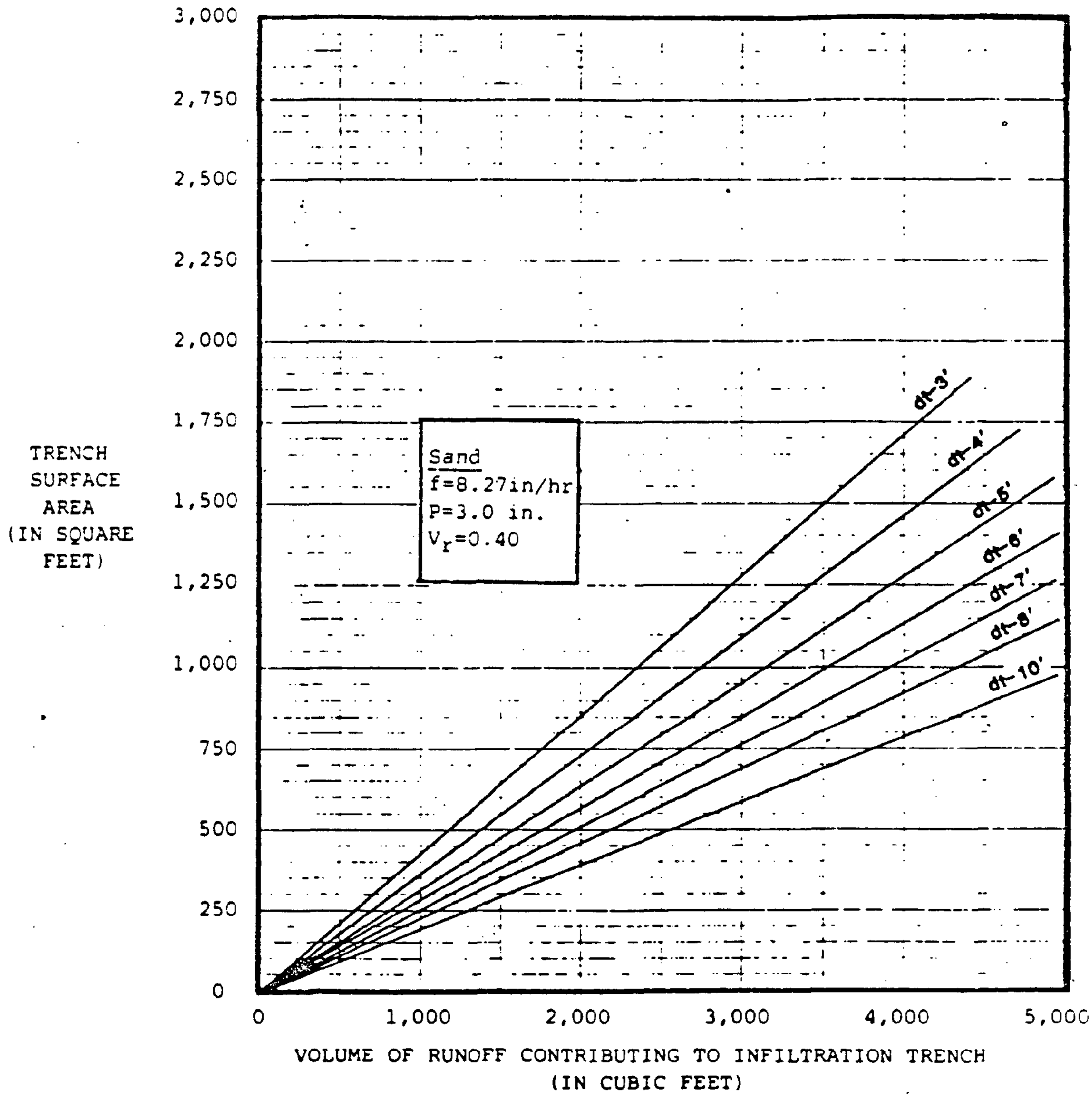


Figure 4-15. Determination of Infiltration Trench Surface Area

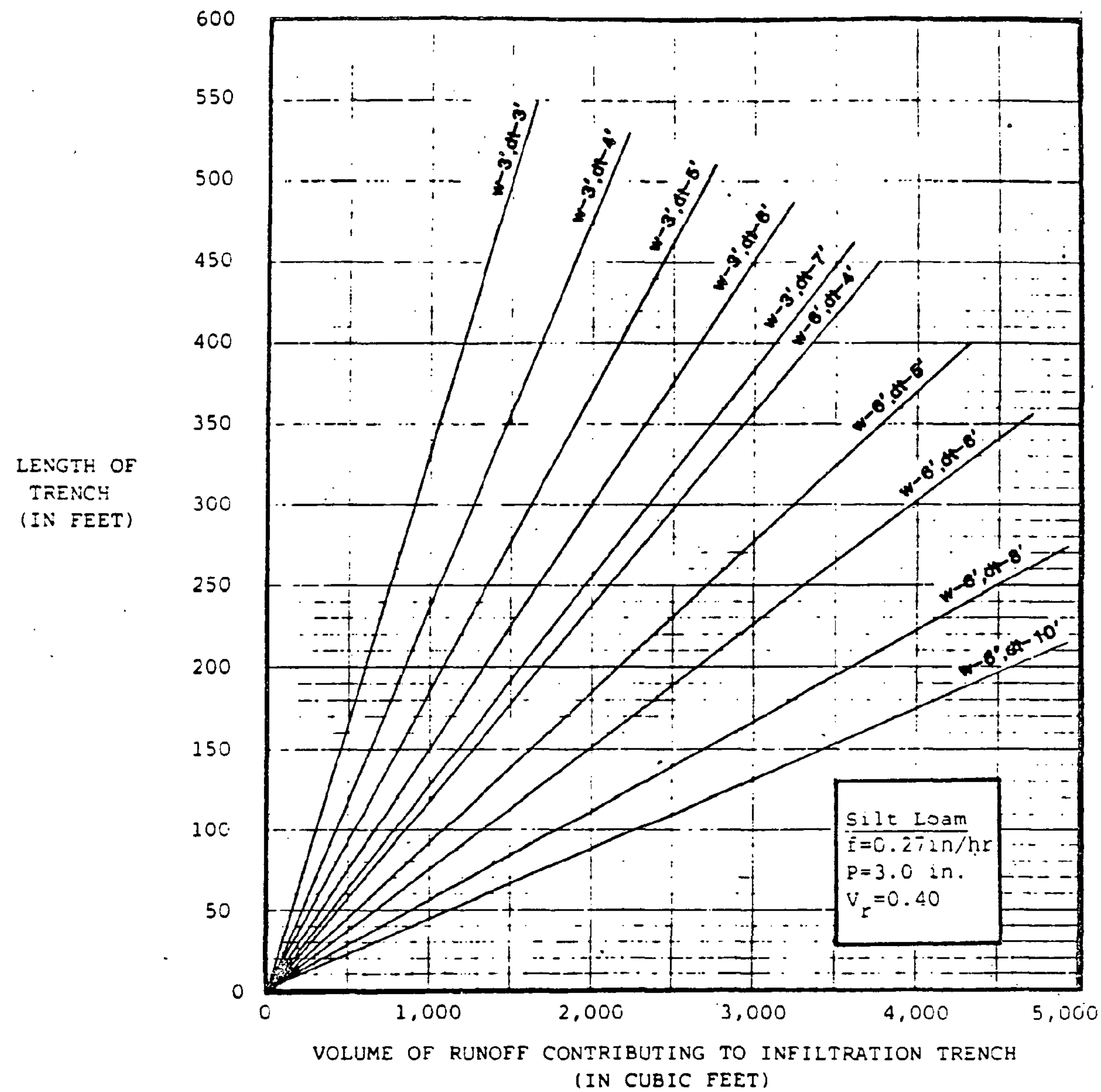


Figure 4-16. Determination of Infiltration Trench Surface Area

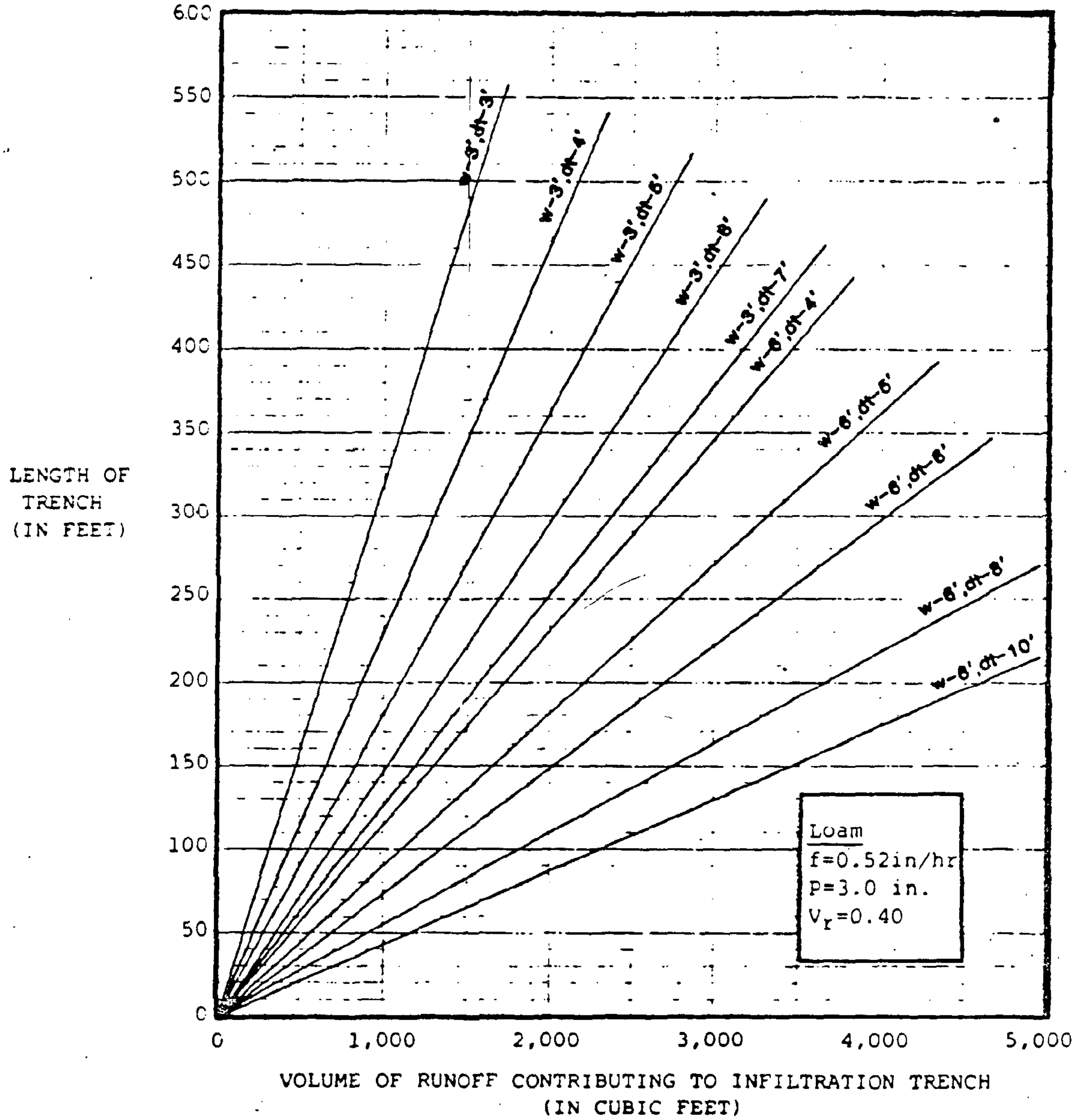


Figure 4-17. Determination of Infiltration Trench Surface Area

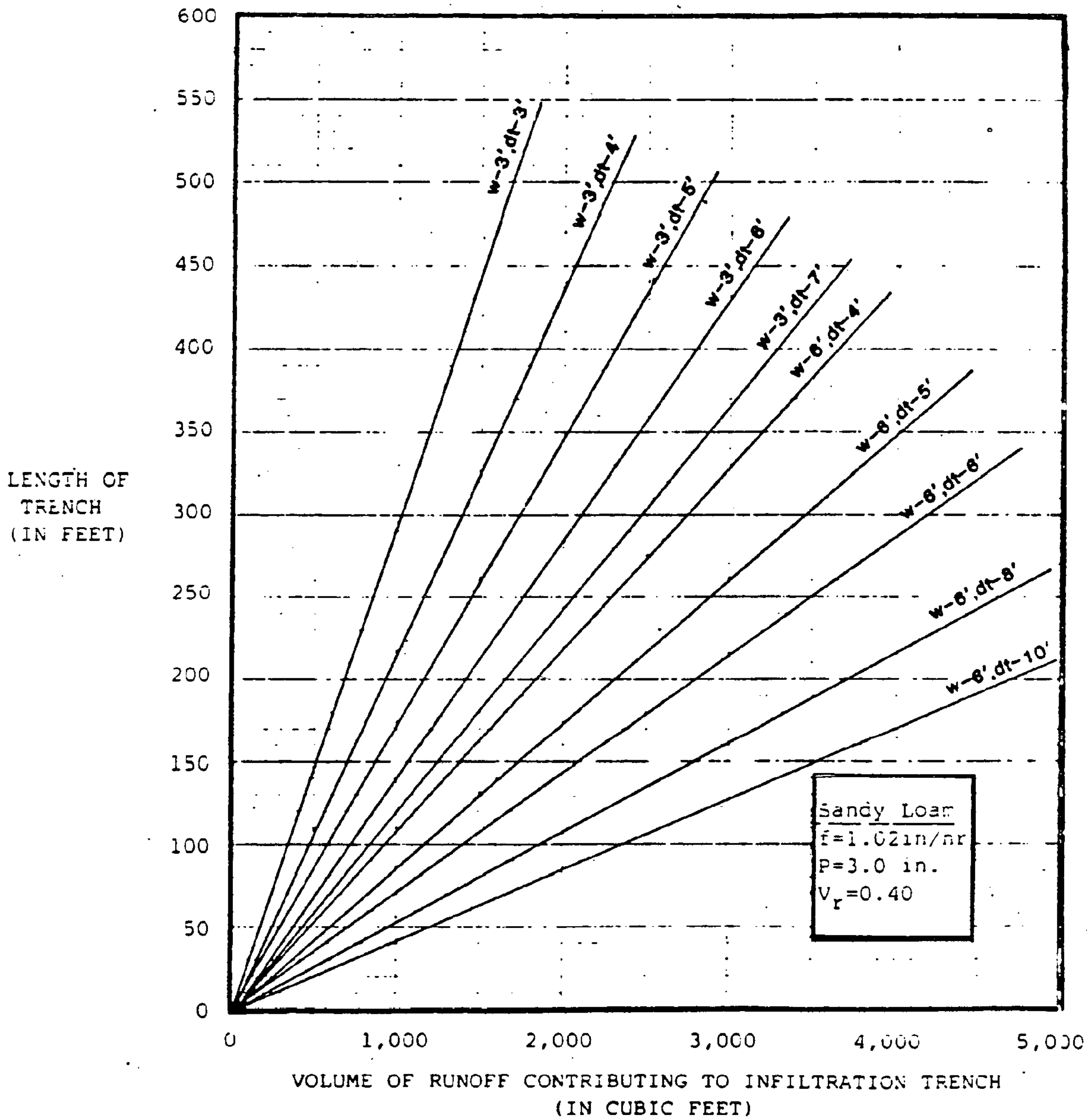


Figure 4-18. Determination of Infiltration Trench Surface Area

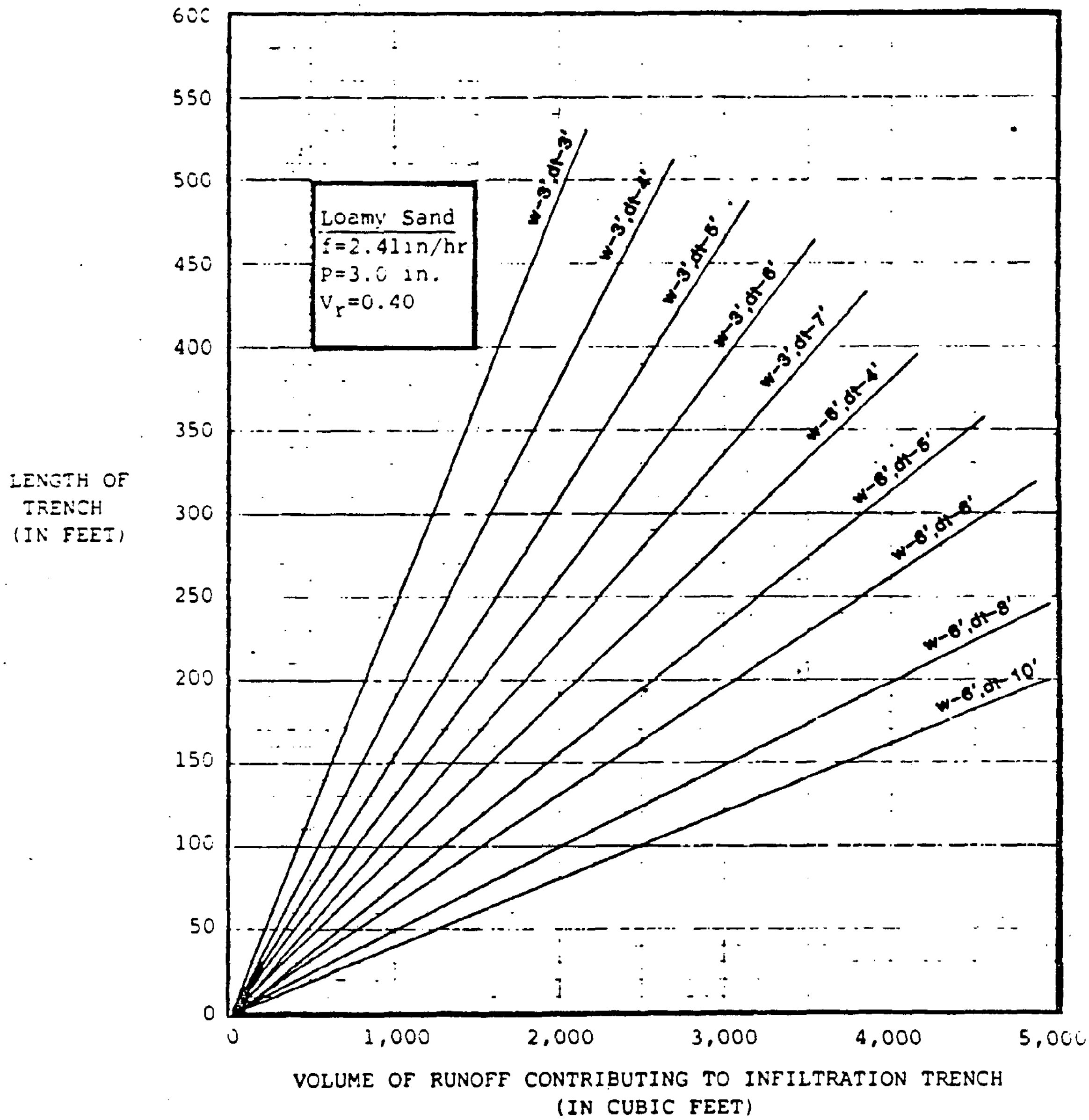


Figure 4-19. Determination of Infiltration Trench Length

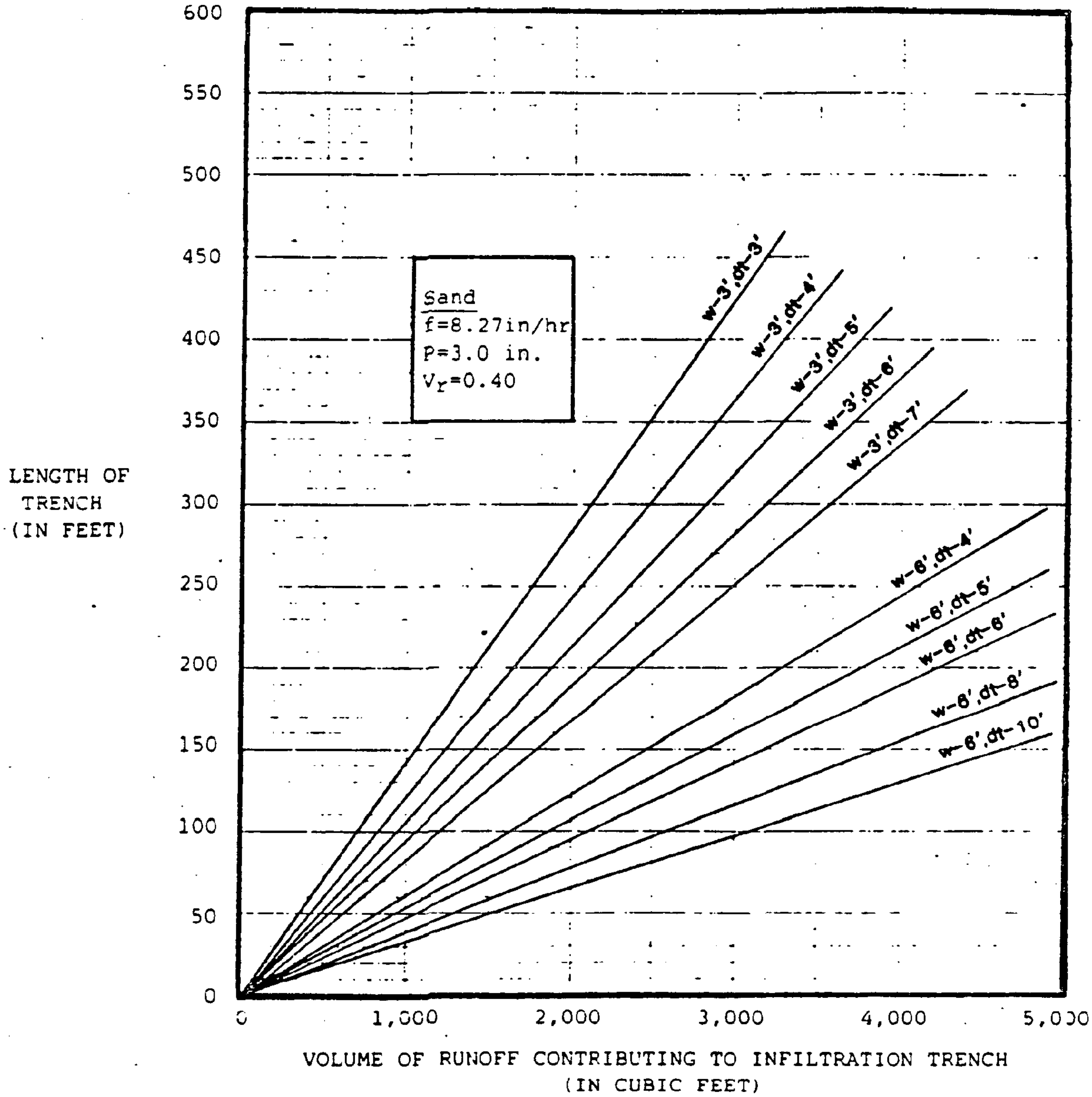


Figure 4-20. Determination of Infiltration Trench Length

4.4 DESIGN OF DRY WELLS

(DW)

Dry well storage is defined as subsurface storage in which inflow is by way of both pipe inlet(s) and infiltrating water through the overlying soil. The volume of storage in the dry well must accommodate runoff from a contributing area (A_c in Figure 4-21) as well as water that infiltrates through the overlying soil (A_w in Figure 4-21).

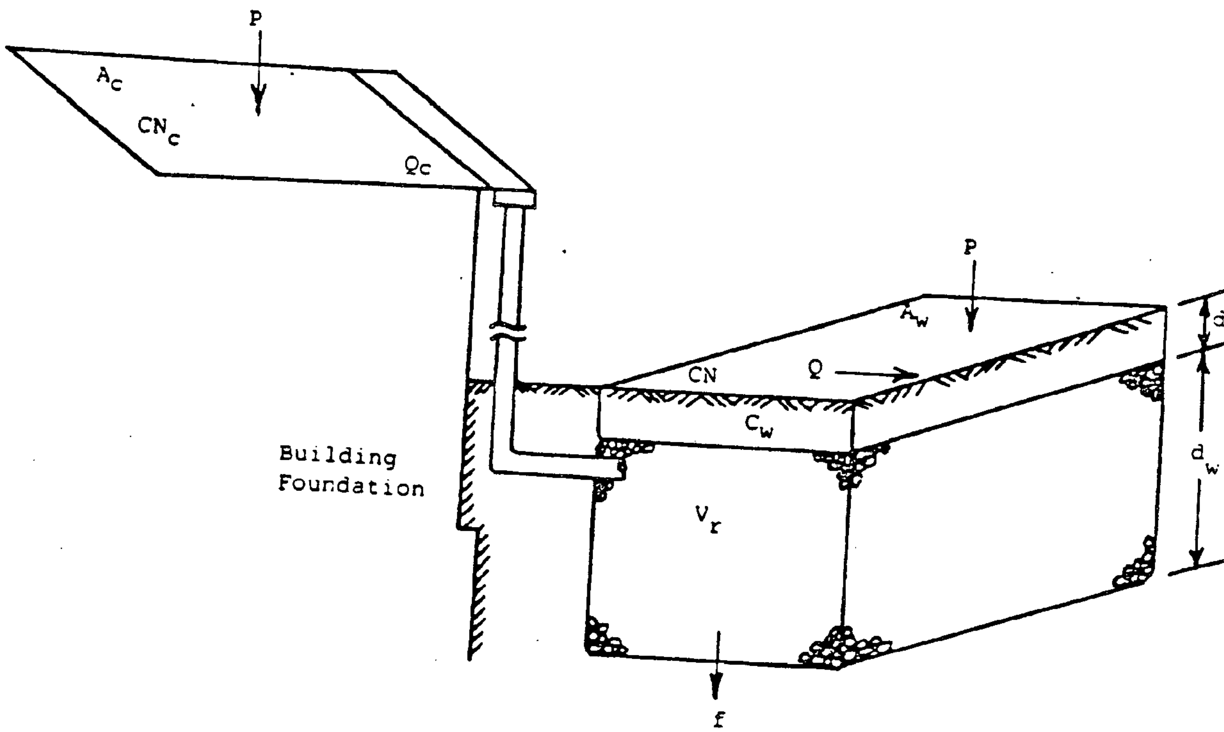
While a dry well serves to control runoff using concepts similar to that of infiltration trenches, the areal extent of the runoff control methods serves as an important distinguishing factor. As used herein, dry wells have small areal extents in comparison to infiltration trenches. The time of concentration of runoff from the contributing area is very small; in fact, it may be considered as instantaneous in comparison to both the duration of the design storm and the smallest time increment for routing through such systems. For example, the time required for rooftop runoff to be discharged from a downspout could probably be measured in seconds rather than minutes.

Site Layout

Dry well storage is subsurface storage in which inflow is by way of pipe inlet(s) draining runoff from rooftop areas A_c with gutters leading directly into the stone filled reservoir area A_w below the overlying soil shown in Figure 4-21. In special cases, the dry well may be designed with a surface inlet to capture runoff from an upland drainage area, although its functioning life may be reduced due to sediments clogging the stone reservoir. A filter fabric material shall be required directly below the overlying soil surface and around the sides and bottom of the dry well. Any surface inlet above the dry well shall have a minimum 20 foot vegetated buffer strip on each side of the inlet. The vegetated buffer strip will prevent sediments from entering the well and clogging the stone voids and thus, increase life of the dry well.

Feasibility Test

Before designing a dry well, it is necessary to determine the textural class of the soils underlying the well such that a feasible design is possible. Soils with infiltration rates a dry well. Those soil textural classes that have slow less than 0.27 inches per hour should not be considered for infiltration rates (i.e. less than 0.27 inches per hour) limit the flow of



<u>Notation</u>

P	=	rainfall depth (ft)
CN_c	=	CN for contributing area
A_c	=	area contributing runoff to dry well (ft^2)
Q_c	=	depth of runoff from contributing area (ft)
A_w	=	surface area of dry well (ft^2)
Q	=	runoff depth from overlying area A_w (ft)
CN	=	CN of overlying soil
C_w	=	water capacity of overlying soil (in/in)
d_o	=	depth of soil overlying dry well (ft)
d_w	=	depth of dry well storage (ft)
V_r	=	void ratio in dry well
f	=	final infiltration rate below dry well (ft/hr)

Figure 4-21. Schematic of a Dry Well

water through the soil. Additionally, the allowable depth of storage may be too shallow to be practical when constructing the structure, based on the maximum storage time of 3 days. Thus, the suitable textural class of the soil underlying the dry well should be either a silt loam, loam, sandy loam, loamy sand, or sand.

The design of a dry well is also based upon the maximum allowable depth of the trench d_{max}. The maximum allowable depth should meet the following criteria:

$$d_{max} = f \times T_s/V_r \qquad (4\text{-}24)$$

where f is the final infiltration rate of the dry well area in inches per hour, T_s is the maximum allowable storage time of 72 hours, and V_r is the void ratio of the stone reservoir. The maximum allowable depths are given in Table 3-2 for selected values of f, T_s, and V_r.

Design Method

The design method is based on controlling the runoff for a specific frequency storm event. The design return period shall be the 1 year frequency storm event. If the discharge associated with the water quality design storm event cannot be managed, a first flush event should be the minimum selected for design.

The design method proposed herein is based on the conceptual framework of Figure 4-21. Rainfall produces runoff from both the surface area of the dry well A_w and the contributing area A_c. Runoff from the contributing area Q_c passes to the dry well by way of a pipe. Rain that falls onto the surface area A_w will run off (Q) according to the curve number (CN) of the dry well area; Q will be based on the overlying soil and grass cover. That which does not run off (i.e., P-Q) will be available for infiltration through the overlying soil and into the dry well. The depth that infiltrates into the dry well during the storm will also depend on the depth of the overlying soil d_o and the water capacity of the overlying soil C_w. The flow out of the base of the dry well will depend on the infiltration rate (f), the area A_w, and the time that the flow into the dry well exceeds the flow out of the dry well, or the effective filling time (T). Values of f should be obtained from Table 3-1. For designs based on the SCS type III storm, a time of one hour will be used for a value of T because, for storm volumes typically used for design, the inflow rate will exceed the outflow rate during a time period less than one hour.

The volume of water that must be stored V_w is the sum of the runoff from the contributing area $(A_c\ Q_c)$, plus the volume of water entering the dry well surface $(P - Q)A_w$ less the volume of water stored in the overlying soil $d_o\ C_w\ A_w$ minus the volume of water exfiltrating out of the dry well bottom (fTA_w):

$$V_w = A_c Q_c + (P - Q - d_o\ C_w)\ A_w - fTA_w \qquad (4\text{-}25)$$

in which $(P - Q - d_o\ C_w)$ must be greater than or equal to 0.0.

The volume of the dry well may be defined in terms of the well geometry. The gross volume of the dry well V_s is equal to the product of the depth d_w and the surface area A_w; V_s also equals the ratio of the volume of the water that must be stored V_w to the void ratio V_r of the aggregate reservoir in the dry well:

$$V_s = V_w / V_r = d_w\ A_w \qquad (4\text{-}26)$$

Combining Equations 4-25 and 4-26 yields the following relationship:

$$d_w\ A_w\ V_r = A_c Q_c + (P - Q - d_o\ C_w)\ A_w - fTA_w \qquad (4\text{-}27)$$

Since both dimensions of the dry well (d_w and A_w) are unknown, Equation 4-27 represents one equation with two unknowns. Thus, there are a number of combinations of d_w and A_w that can be used. If the value of d_w were set based on either the location of the water table or the maximum allowable depth d_{max}, then the area A_w could be determined by rearranging Equation 4-27.

$$A_w = \frac{Q_c\ A_c}{V_r d_r - P + Q + d_o C_w + fT} \qquad (4\text{-}28)$$

Equation 4-28 is used to graph the relationship between A_w and d_w for values of the other variables, shown in Figures 4-22 through 4-26. The overlying soil was assumed to be a 12 inch deep loam textural class soil having a water capacity of 0.19 in/in and a runoff curve number of 61. All variables used in Equation 4-28 must be in units of feet.

Design Procedure

1. From the selected design rainfall (P) and runoff curve numbers, compute the runoff depths for the overlying soil (Q, based on grass cover) and the contributing area (Q_c, curve number = 98 for impervious surface).

2. Compute the maximum allowable dry well depth d_{max} from the feasibility equation, $d_{max} = fT_s/V_r$. Select the dry well design depth d_w based on the depth that is at least two feet above the seasonal high groundwater table, or a depth less than or equal to d_{max}, whichever results in the smaller depth.

3. Determine the dry well surface area A_w from Figures 4-22 through 4-26 or compute the required surface area of the dry well from Equation 4-28:

$$A_w = \frac{Q_c A_c}{V_r d_w - P + Q + d_o C_w + fT}$$

C_w and f are obtained from Table 3-1 based on the overlying and underlying soil types of the dry well, respectively. Use a T value of one hour for design. If the variables Q_c A_c, V_r d_w, P, Q, C_w d_o, fT are different than those given in the Figures, use Equation 4-28 for the exact solution.

In the event that the side walls of the dry well must be sloped for stability during ocnstruction, the surface dimensions of the dry well area should be based on the following equation:

$$A_w = (L-Zd_w)\ (W - Zd_w)$$

where L and W are the top length and width, and Z is the dry well side slope ratio. The design procedure would begin by selecting a top width (W) that is greater than $2Zd_w$ for a specified side slope ratio (Z). The side slope ratio value will depend on the soil type and depth of dry well. The top length (L) is then determined as:

$$L = Zd_w + \frac{A_w}{(W - Zd_w)}$$

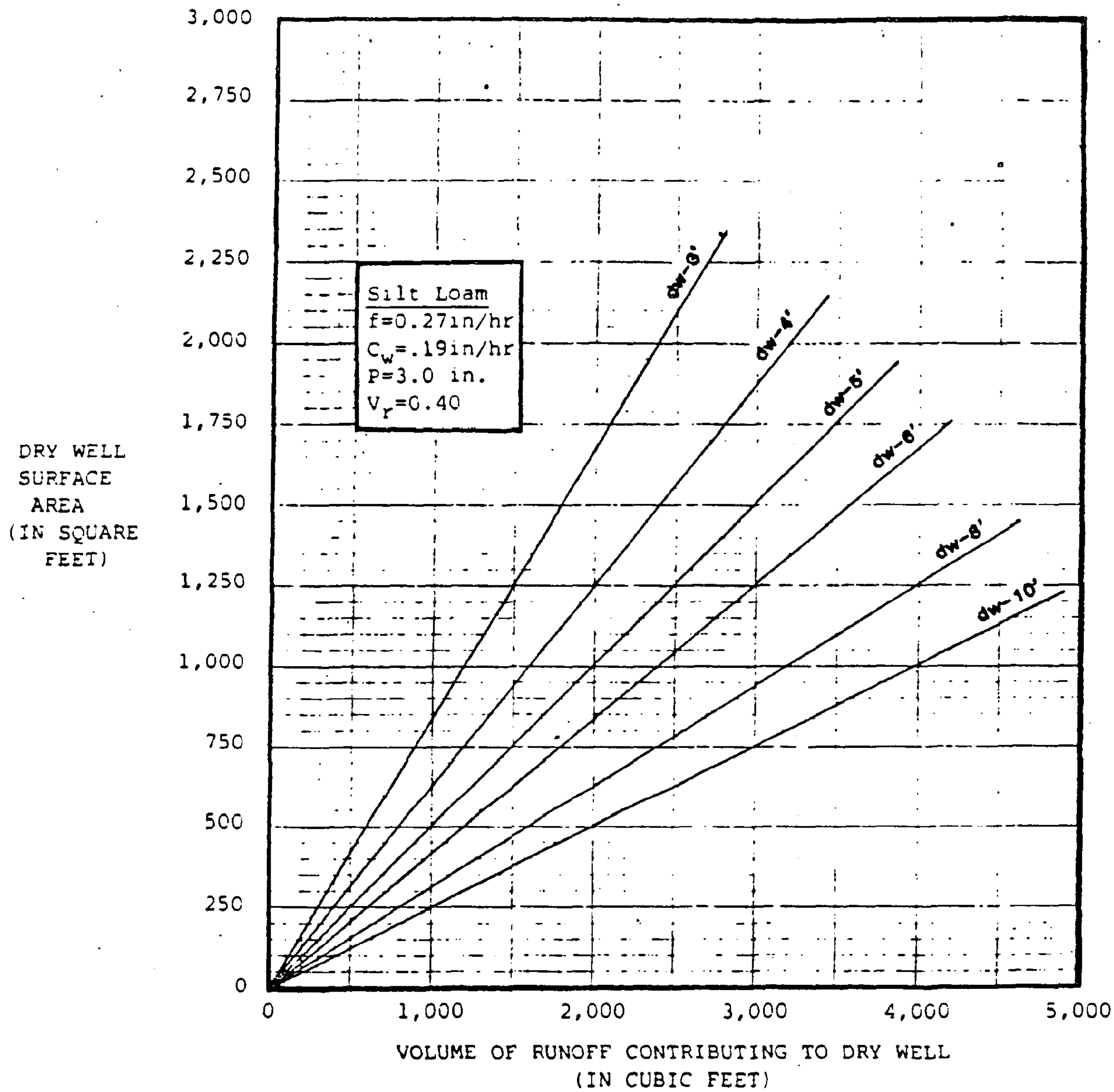


Figure 4-22. Determination of Dry Well Surface Area

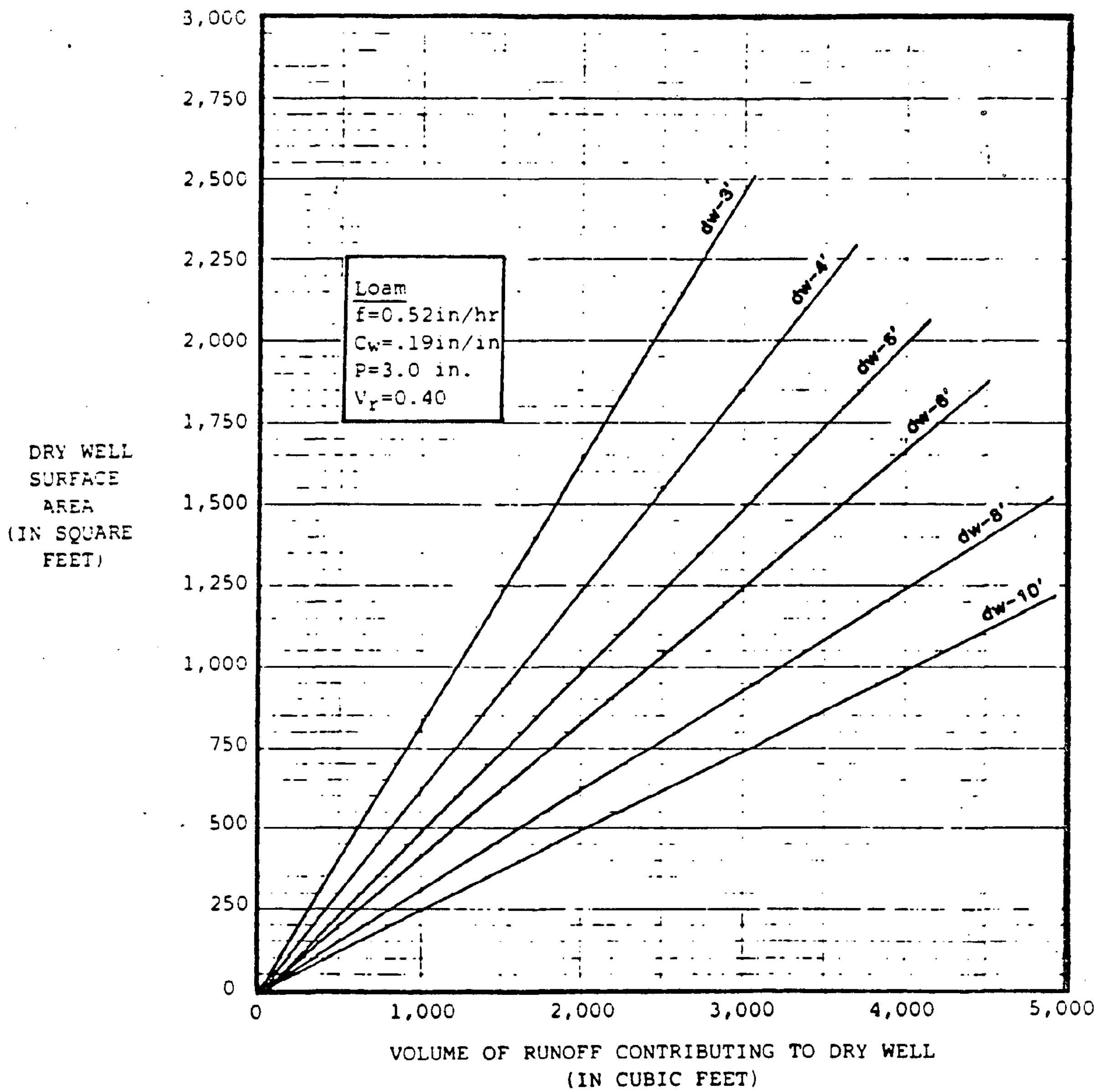


Figure 4-23. Determination of Dry Well Surface Area

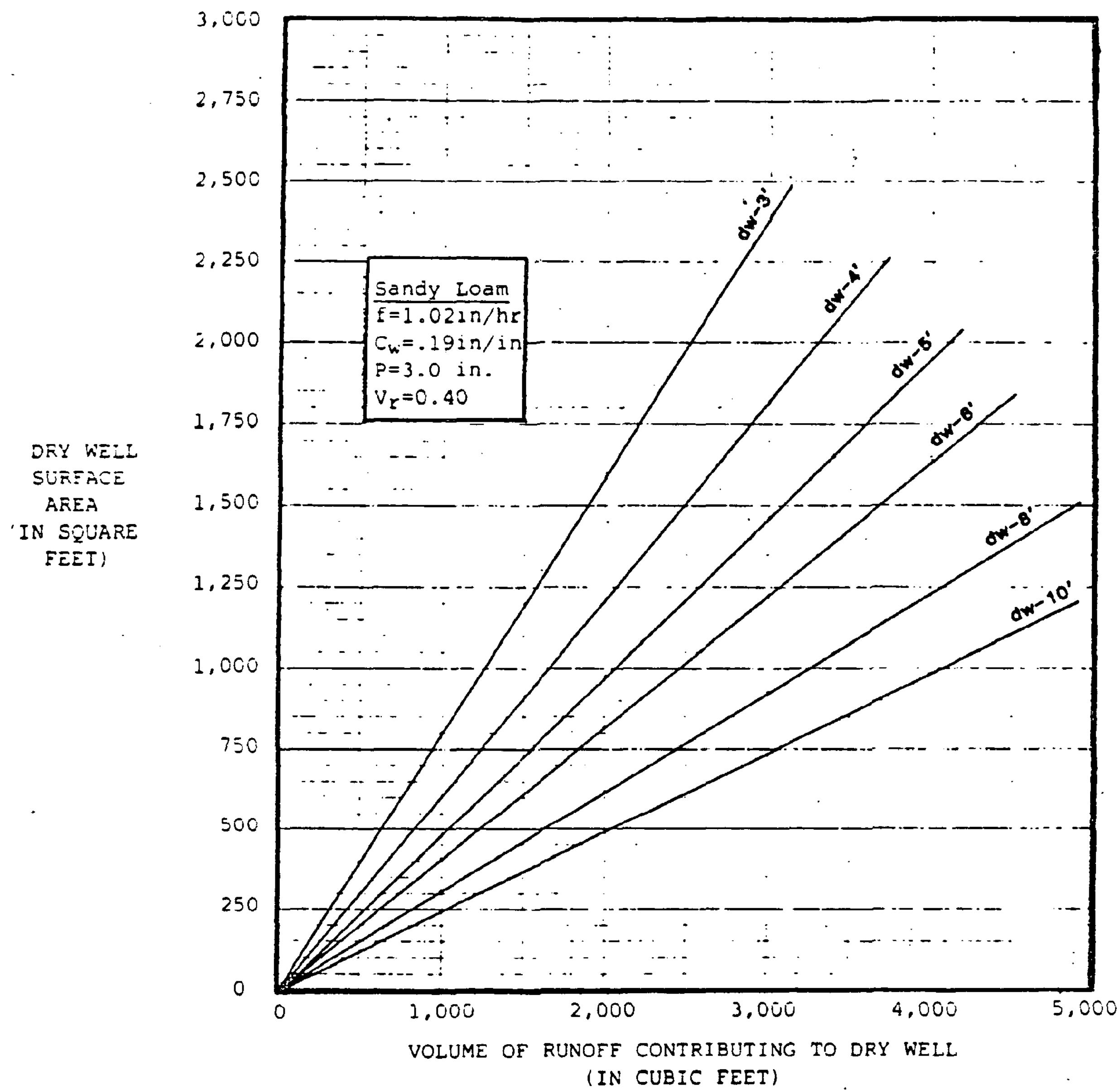


Figure 4-24. Determination of Dry Well Surface Area

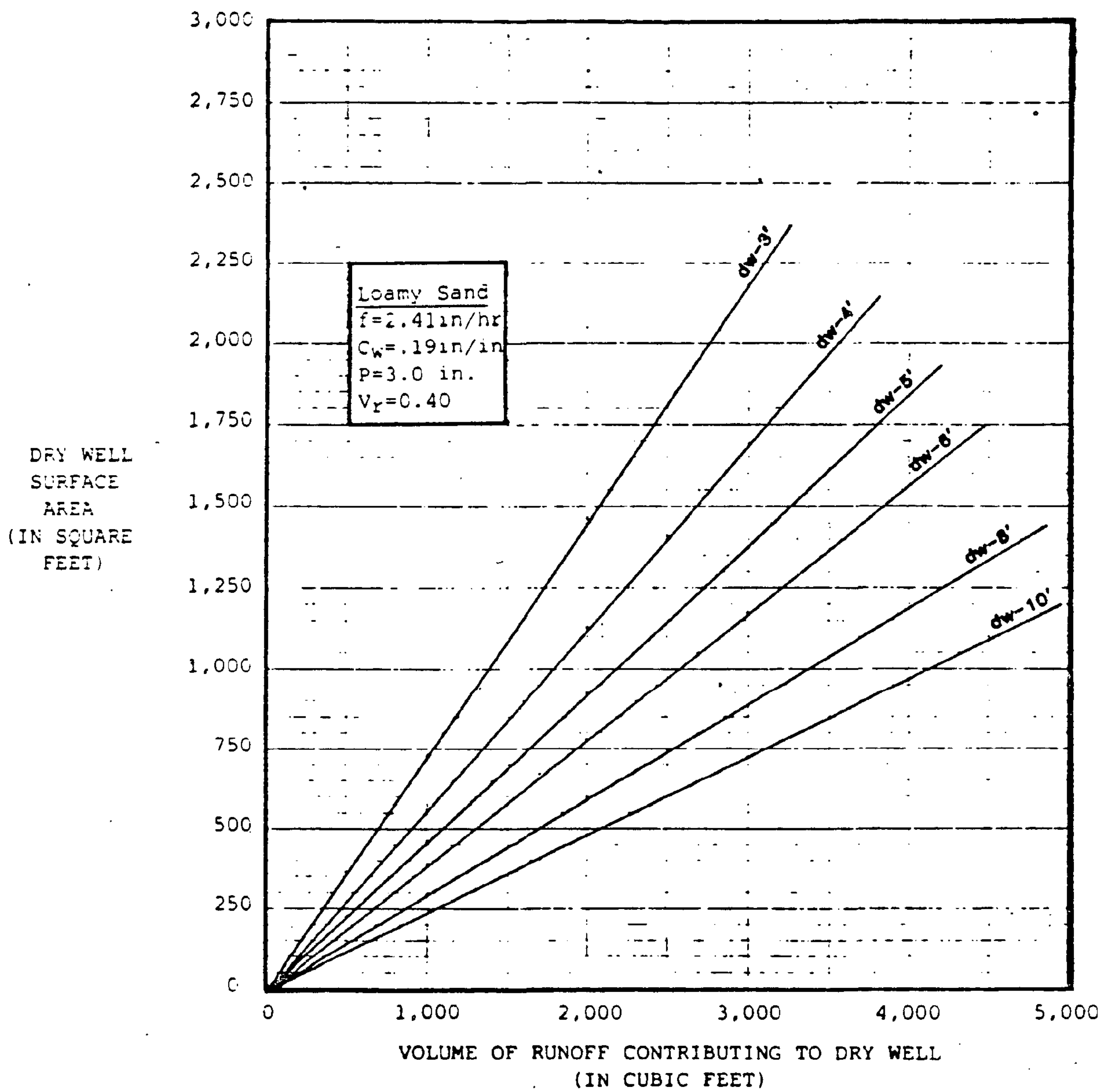


Figure 4-25. Determination of Dry Well Surface Area

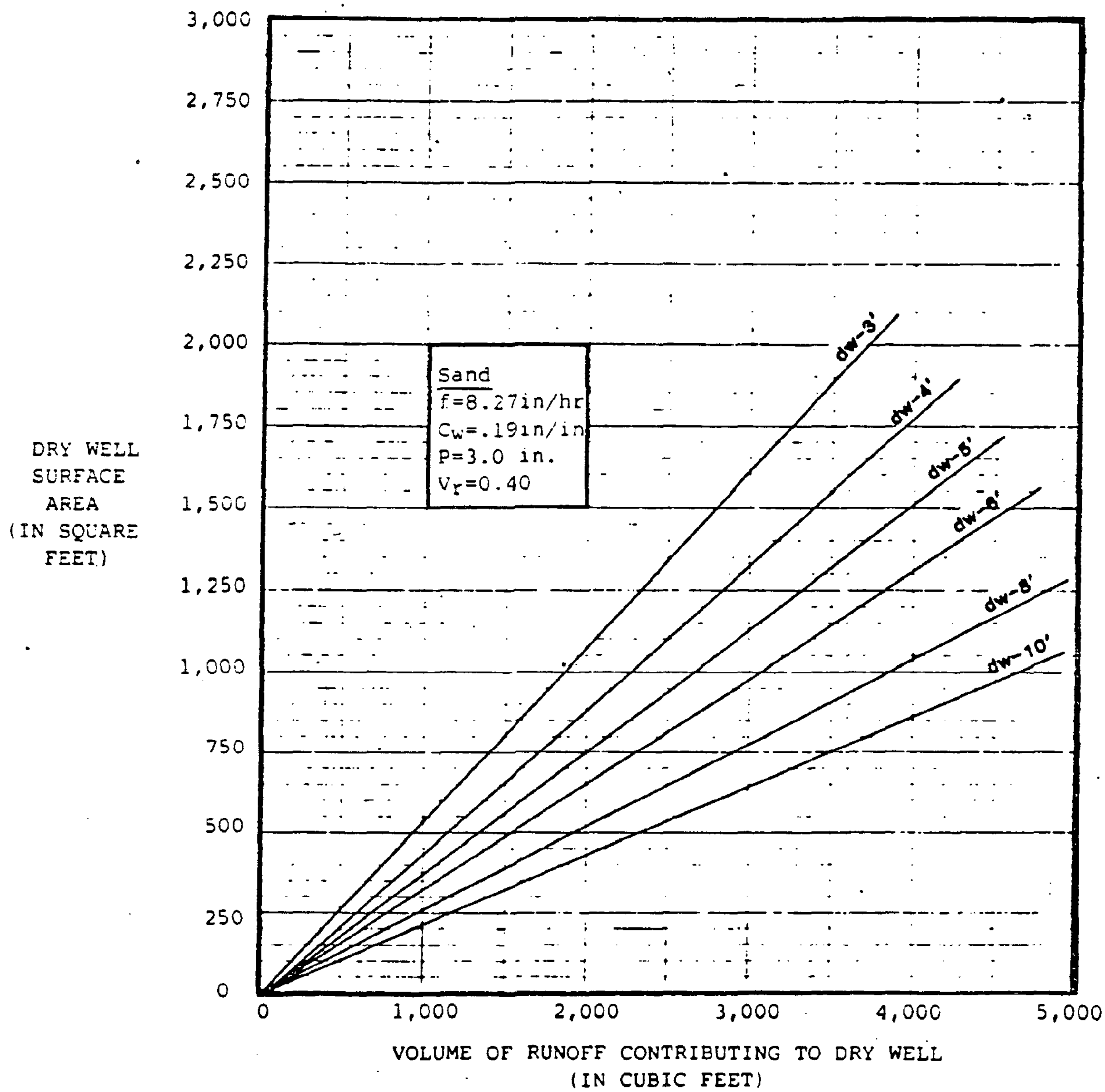


Figure 4-26. Determination of Dry Well Surface Area

4.5 DESIGN OF VEGETATED SWALES

(VS)

A vegetated swale with a check dam is a grassed channel with a small earth check dam that is used to store and infiltrate storm runoff. The small check dams will generally be 6 to 24 inches in height to create small infiltration pools. The use of small check dams to create infiltration pools is limited to swale slope gradients of 5 percent or less. Swale gradients greater than 5 percent may cause erosion and will limit the volume of runoff stored behind the check dams. The volume of water stored by a swale will depend on the land slope, the depth, and width of the swale at the top of the check dam.

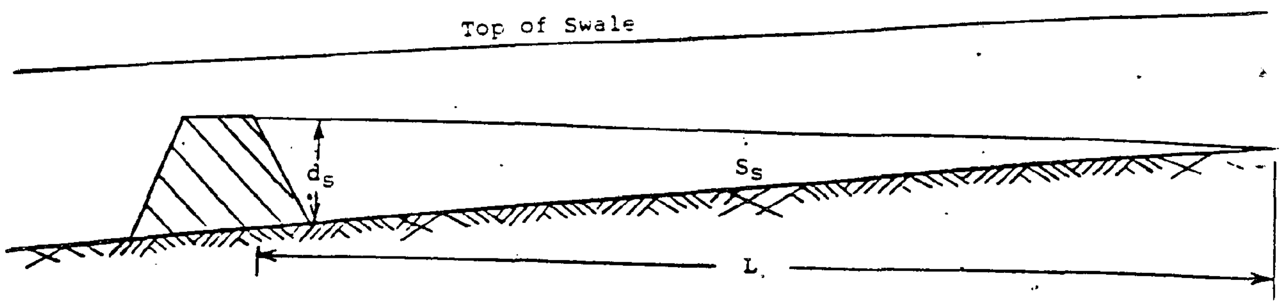
A vegetated swale without a check dam is encouraged over conventional curbs and gutters to remove some nutrients and pollutants from runoff and reduce the volume of runoff for small storm events (less than a 2 year frequency storm event). The design of swales without check dams can be accomplished with the existing SCS design methods by the appropriate modification of the flow length and the time of concentration.

Site Layout

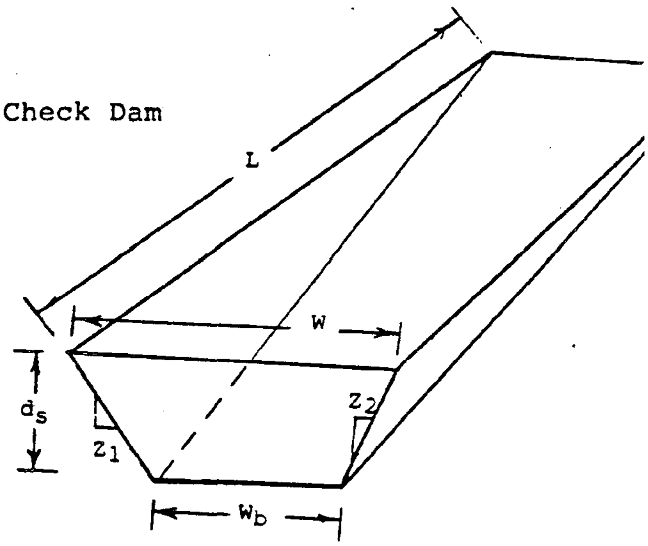
The site layout will consist of the portion of the watershed that contributes direct runoff to the swale area or the upland area, which is denoted as A(u); and the portion of the watershed allocated for swale storage, which is denoted as A(s). It is important to note that the upland area (A(u)) does not include the area allotted to the swale surface (A(s)). Swale locations are usually either on the side or back of the property line or along the side of roadways. They are probably most applicable in parking lots where they can be used in between parking bays. This will break up the typical "sea of asphalt" and can be used for landscaping purposes by planting trees in the swales. Installation of berms or check dams at certain intervals along the length of the swale will result in storage. Figure 4-27 shows the schematic of a vegetated swale with a check dam.

Feasibility Test

Before designing a vegetated swale, it is necessary to determine the textural class of soils underlying the swale such that a feasible design is possible. Soils with infiltration rates less than 0.27 inches per hour should not be



(a) Cross Section of Swale with Check Dam



(b) Dimensional View of Swale Impoundment Area

<u>Notation</u>

L = length of swale impoundment area per check dam (ft)

d_s = depth of check dam (ft)

S_s = bottom slope of swale (ft/ft)

W = top width of check dam (ft)

W_b = bottom width of check dam (ft)

Z_1 & Z_2 = ratio of horizontal to vertical change in swale side slope (ft/ft)

Figure 4-27. Schematic of Vegetated Swale with Check Dam considered for a vegetated swale. Those soil textural classes that have slow infiltration rates (i.e. less than 0.27 inches per hour) limit the flow of water through the soil. Additionally, the allowable depth of storage may be too shallow to be practical when constructing the structure, based on the maximum ponding time of 24 hours. Thus, the suitable textural class of the soil underlying the swale should be either a silt loam, loam, sandy loam, loamy sand, or sand.

The design of a vegetated swale is also based upon the maximum depth of the check dam d_{max}. The maximum allowable depth should meet the following criteria:

$$d_{max} = f \times T_p \qquad (4\text{-}29)$$

where f is the final infiltration rate of the swale area in inches per hour, and T_p is the maximum allowable ponding time of 24 hours. The maximum allowable depths are given in Table 3-2 for selected values of f and T_p.

Design Method

The design method is based on controlling the runoff for a specific frequency storm event. The increase in peak discharge associated with the 2-year storm event can be managed, or the 1-year water quality storm can be selected for design.

The vegetated swale is sized to store the runoff volume that contributes from the upland area for a selected design storm. The design volume of the swale V_w equals the upland runoff volume $Q_u A_u$ to the swale, plus the volume of rain that falls on the surface of the swale (PA_s), minus the exfiltration volume (fTA_s) out of the bottom of the swale. Based on the SCS type III storm, the effective swale filling time will generally be less than a two hour duration. The effective filling time is the duration in which flow into the swale exceeds the exfiltration out of the swale. Thus, a duration of 2 hours is used for the value of T. The volume of water that must be stored in the swale V_w is defined as:

$$V_w = Q_u A_u + PA_s - fTA_s \qquad (4\text{-}30)$$

where units of feet are used to get volumes in terms of cubic feet. The upland runoff depth Q_u for the upland contributing area A_u is determined as:

$$Q_u = \frac{(P - 0.2\,S)^2}{P + 0.8S}$$

The volume of rainfall and runoff stored in the swale may be defined in terms of the swale geometry. The total volume of swale storage is determined as:

$$V_w = \frac{ds\ (W + W_b)\ L}{4}\ (N_s) \qquad (4\text{-}31)$$

where d_s is the depth of the swale check dam (ft), W is the swale top width (ft), W_b is the swale bottom width (ft), L is the length of each swale impoundment behind a check dam (ft), and N_s is the number of check dams along the total hydraulic length of the swale L_t. The length (L) behind each swale check dam may be determined by:

$$L = \frac{d_s}{S_s} \qquad (4\text{-}32)$$

where S_s is the longitudinal slope (ft/ft) along the length of the swale. The number of check dams N_s that may be installed along the total length of swale L_t may be determined by:

$$N_s = \frac{L_t}{L} \qquad (4\text{-}33)$$

By setting Equations 4-36 and 4-38 equal, the total hydraulic length of the swale needed to store the upland runoff is given as:

$$L_t = \frac{Q_u\ Au}{\frac{ds}{4}\ (W + W_b) + W(fT - P)} \qquad (4\text{-}34)$$

where W is the top width of the swale check dam and is determined as:

$$W = W_b + d_s\ (Z_1 + Z_2) \qquad (4\text{-}35)$$

where Z_1 and Z_2 are the side slope ratios of the swale cross sectional area, horizontal to vertical. Frequently, the side slope ratios will be the same on both sides of the swale, given Z (ft/ft); substituting into Equation 4-35 yields:

$$W = W_b + 2d_s\ Z \qquad (4\text{-}36)$$

Swale cross sections may also be vee-shaped or parabolic and the top widths for each of these shapes are given in Figure 3-10.

When the site layout is such that it restricts the swale dimensions to a specific configuration, the level of control provided, given swale dimensions, may be determined as:

$$Q_s = \frac{V_w}{A_u} \qquad (4\text{-}37)$$

where Q_s is the depth of runoff controlled by the swale and V_w is determined by Equation 4-31 for the given swale dimensions. All parameters in the equations must be converted to feet.

Design Procedure

1. Determine the after development runoff volume (Q_a) from the SCS TR-55 Manual. Equation 4-11 is used to compute the upland runoff volume (Q_u):

$$Q_u = \frac{(P - (0.2S)^2}{P + .08\ (S)}$$

2. Compute the maximum allowable swale depth d_{max} from the feasibility equation, $d_{max} = fT_p$. Select the swale design depth d_s based on a depth that is at least two feet above the seasonal high groundwater table, or the depth lessor equal to d_{max}, whichever results in the smaller depth.

3. The swale surface area dimensions can be determined from Equations 4-34 and 4-36. The bottom width W_b is selected along with the side slope ratio (Z), and depth of check dam D_s. The swale top width (W) and total hydraulic length L_t may be computed as:

$$W = W_b + 2\ d_s\ Z$$

and:

$$L_t = \frac{Q_u\ Au}{\frac{ds}{4}\ (W_s + W_b) + W(fT - P)}$$

4. The number of check dams needed to impound and store the

increased runoff volume is determined as:

$$N_s = \frac{L_t}{L}$$

The maximum require spacing between check dams is computed as:

$$L = \frac{d_s}{S_s}$$

If L_t is restricted by the site layout, the level of control provided by the swales is determined by equation 4-37:

$$Q_s = \frac{V_w}{A_u}$$

where:

$$V_w = \frac{d_s \; (W + W_b\,)\,L}{4} \; (N_s)$$

The same design procedure above may be used for rate control, except that Q_u used above would be equal to the increase in runoff volume (or Q_a - Q_b).

APPENDIX A

STORM WATER MANAGEMENT REGULATIONS

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7:8-1.2 Construction
7:8-1.3 Definitions
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8. Aestetics
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STORM WATER MANAGEMENT REGULATIONS

Subchapter 1 - GENERAL PROVISIONS

7:8-1.1 Purpose and Authority

This chapter shall implement the provisions of the New Jersey Storm Water Management Act, P.L. 1981, c. 32, which amends and supplements the Municipal Land Use Law, N.J.S.A. 40:55D-1 et seq. These Storm Water Management Regulations establish minimum requirements and controls to compensate for the differences in the hydrologic response of the watershed from the undeveloped to the developed condition. The Storm Water Management Act further creates a State grant program, (however, no funds have been appropriated for this purpose as of this time). Nothing in these regulations shall change the assigned duties of counties and municipalities responsible for approval of storm water management provisions, submitted as part of site plans, and subdivisions as established by the Municipal Land Use Law.

7:8-1.2 Construction

(a) This chapter shall be liberally construed to permit the Department to discharge its statutory function under the New Jersey Storm Water Management Act, P.L. 1981, c.32.

(b) The Commissioner may amend, repeal or rescind this chapter from time to time in conformance with the Administrative Procedure Act, N.J.S.A. 52:14B-1 et seq.

7:8-1.3 Definitions

"Agricultural Development" means land uses normally associated with the production of food, fiber and livestock for sale. For purposes of this chapter, such uses shall not include the development of land for the processing or sale of food and the manufacture of agriculturally related products.

"Commissioner" means the Commissioner of the Department of Environmental Protection, or his appointed designee.

"Department" means the Department of Environmental Protection.

"Flood Hazard Areas" means the floodway and flood fringe areas determined by the Department under section 3 of the Flood Hazard Areas Control Act (P.L. 1979, c. 359).

"Flood Plain" means the flood hazard areas of delineated streams and areas inundated by the 100 year flood in non-delineated areas.

"Floodway" means the channel of a natural stream and portions of the flood hazard areas adjoining the channel, which are reasonably required to carry and discharge the flood water or flood flow of any natural stream.

"Impervious Surface" means any natural or man-made surface which does not permit infiltration of water and causes surface runoff.

"Major Development" means that, in addition to the definition of development in the Municipal Land Use Law N.J.S.A. 40:55D-4; any activity must satisfy 1 or 2 below:

1. Any site plan or subdivision plan that will ultimately cover one or more acres of land with additional impervious surfaces.

2. Any construction of one or more of the following uses; (i) feeding and holding areas that provide for more than 100 head of cattle or 15,000 hens, 500 swine, 40000 turkeys, 10,000 ducks; this section shall also apply to all other equivalent numbers of animals units as determined by the SCS Agricultural Waste Management Field Manual for measuring BOD producing potential. (ii) pipelines, storage, or distribution systems for petroleum products or chemicals; (iii) storage, distribution or treatment facilities (excluding individual on-site sewage disposal systems) for liquid waste; (iv) solid waste storage, disposition, incineratión or landfill; (v) quarries, mines or borrow pits; and (vi) land application of sludge or effluents; (vii) storage, distribution or treatment facilities for radioactive waste.

   "MLUL" means the Municipal Land Use Law N.J.S.A. 40:66D1 et seq.

   Non-point Source Pollution" means pollution from any source other than from any discernible, confined and discrete conveyances, and shall include, but not be limited to, pollutants from agricultural, silvicultural, mining, construction, subsurface disposal and urban runoff sources.

   "Ordinance" means the same as "development regulation" under the MLUL.

   "Recharge" means the replenishment of underground water reserves.

   "Storm Water Runoff" means flow on the surface of the ground, resulting from precipitation.

7:8-1.4 Applicability

(a) Any storm water management plans or ordinances hereafter adopted in New Jersey shall comply with this chapter.

(b) Phase I is applicable only to new developments, and not to the remedy of existing runoff pollution situations. Specifically, as regards animal feeding and holding areas, it applies only to new agricultural facilities or additions to facilities involving additional animals in amounts sufficient to constitute a major development.

7:8-1.5 Program Information

Unless otherwise specified, any questions concerning the requirements of this chapter shall be directed to the Water Supply and Watershed Management Administration, Division of Water Resources, New Jersey Department of Environmental Protection, CN-029, Trenton, New Jersey 08625.

7:8-1.6 Severability

If the provisions of any article, section, subsection, paragraph, subdivision or clause of this chapter shall be judged invalid by a court of competent jurisdiction, such order or judgement shall not affect or invalidate the remainder of any article, section, subsection, paragraph, subdivision or clause of this chapter.

7:8-1.7 Relationship to other permitting programs

Nothing in this chapter shall be construed as limiting the rights of other agencies or entities, such as the Pinelands Commission, from imposing stricter standards or other requirements as allowed by statute.

Subchapter 2 - PROVISIONS FOR PREPARATION OF PLANS AND ORDINANCES

7:9-2.1 Objectives

(a) A storm water management plan and its implementing ordinance or ordinances shall be designed:

1. To reduce artificially induced flood damage to public health, life and property;

2. To minimize increased storm water runoff from any new land development where such runoff will increase flood damage;

3. To maintain the adequacy of existing and proposed culverts and bridges, dams and other structures;

4. To induce water recharge where natural storage and geologically favorable conditions exist where practical;

5. To prevent, to the greatest extent feasible, an increase in non-point source pollution;

6. To maintain the integrity of stream channels for their biological functions, as well as for drainage and other purposes;

7. To reduce the impact of development upon stream erosion;

8. To reduce erosion from any development or construction project;

9. To minimize the increase in runoff pollution due to land development, which otherwise would degrade the quality of water and may render it both unfit for human consumption and detrimental to biological life; and

10. To preserve and protect water supply facilities and water resources by means of controlling increased flood discharges, stream erosion, and runoff pollution.

7:9-2.2 Schedule for Completion and Submission of Plans and Ordinances

(a) If a grant for 90 percent of the costs for the preparation of the plan is provided by the Department pursuant to section 6 of the Act the storm water management plan shall be completed by the municipality within one year from the date of promulgation of storm water management regulations by the Commissioner, or by the next reexamination of the municipality's master plan required pursuant to N.J.S.A. 40:55-D-89 whichever is later. The storm water management plan shall be an integral part of each municipal master plan as provided by N.J.S.A. 40:55D-28. Each storm water management ordinance or ordinances prepared under such a grant shall be adopted by the municipality within one year of the completion of the storm water management plan and shall be revised thereafter as needed. Such a storm water management plan, control ordinance or resolution prepared by counties, municipalities or designated regional agencies shall be prepared in accordance with this Chapter.

7:9-2.3 County Review Process

(a) Each municipality shall submit its storm water management plan and implementing ordinance adopted pursuant to this Act to the county agency or county water resources association, designated by the freeholders, for approval. The implementing ordinance shall not take effect without county approval.

(b) The agency or association shall approve, conditionally approve, or disapprove said plan and/or ordinance. It shall review its compatibility with applicable municipal, county regional or State storm water management and flood control plans. It shall consult the appropriate Soil Conservation District and verify that the coordination by the municipality and the District has been satisfactorily accomplished, as specified in N.J.A.C. 7:8-3.3. No storm water management plan or ordinance shall be approved which fails to meet the State storm water management standards, established by this chapter. The agency or association shall set forth in writing its reasons for disapproval of any plan or ordinance, or in the case of the issuance of a conditional approval, the agency or association shall specify the necessary amendments to the plan or ordinance to the municipality. Once conditions, if any, are met by the municipality the plan and/or ordinance shall be deemed approved.

7:9-2.4 Failure of County to Approve

Where the agency or association fails to approve, conditionally approve, or disapprove a plan or ordinance within sixty (60) days of receipt of the plan or ordinance, the plan or ordinance shall be considered approved.

7:9-2.5 Notification to the State

Upon receipt of each completed municipal storm water management plan and ordinance, the designated county agency shall notify the Department of its receipt and keep an up-to-date accounting of its standing in the approval process. The county agency shall submit copies of the approved plans and ordinances to the Department and shall provide access to all other relevant records to Department personnel.

7:9-2.6 Exceptions

The Commissioner may upon application by any appropriate agency grant an exception from any of the objectives listed in N.J.A.C. 7:8-2.1(a) 1 through 10 above, as provided for in Sections 3 and 4 of the Act provided that the Commissioner shall determine that such exception will not materially increase flood damage, non-point source pollution, or erosion within or without the municipality. Any municipal request for such exemptions shall be accompanied by proof of notice to all affected municipalities of such request and the request shall be submitted to the State through the appropriate county planning agency.

7:9-2.7 Enforcement

No building permit shall be issued in violation of an adopted ordinance. Any such issuance shall be in violation of the MLUL and subject to the enforcement provisions thereunder.

7:9-2.8 Periodic Reexamination

In accordance with the MLUL, storm water management plans and storm water control ordinances shall be included in the re-examination of the master plan and development regulations.

7:9-2.9 Technical Assistance

Counties, county planning agencies and county water resources associations are authorized and encouraged to provide technical assistance and planning grants to municipalities to assist in the preparation and revision of municipal storm water management plans and implementing ordinances.

Subchapter 3 - ELEMENTS OF PLAN AND ORDINANCE

7:8-3.1 Planning Phases

(a) Planning for storm water management is designed in two phases. The Phase I plan is targeted at preventive measure to be applied to the site plan and subdivision review process. It shall identify existing control requirements and establish plans and ordinances in order to meet the standards in these regulations for at least the short term. The Phase II plan shall provide for the long term comprehensive planning of alternative preventive storm water management measures in conjunction with remedial storm water management measures.

(1) Phase I

i. A Phase I storm water management plan shall consist of the following elements:

1. A statement concerning how the plan will achieve the goals of the Act.

2. A delineation of jurisdictional authority and responsibility in the Phase I plan area. This may include a fee schedule for implementation.

3. an evaluation of existing county and local storm water management plans and ordinances. This evaluation shall examine the consistency of the existing ordinances with regard to the water quantity/quality objectives and minimum standards discussed in this chapter.

4. An evaluation of needs. This evaluation shall consist of two parts: A) a general assessment of those items necessary for the county and/or local ordinances to achieve full compliance with this chapter including but not limited to soil surveys, natural resource inventories and pertinent elements of local and county master plans; and B) an estimate of the technical (personnel and physical resources) and institutional needs necessary to undertake implementation of the Phase I plan.

5. Develop a recommended storm water management ordinance.

ii. Within one year following the completion of the Phase I plan, municipalities shall adopt ordinances which are to be consistent with the policies and principles of the Phase I plan. These ordinances shall be amended, as required, following the adoption of the Phase II plan. Such ordinances must be adopted if the Department provides a grant pursuant to Section 6 of the Act.

2. Phase II

i. A Phase II storm water management plan will be based upon a detailed analysis of alternative storm water management approaches on an integrated or regional basis. The plan will consist of a system of non-structural and/or structural storm water management programs to mitigate flooding and non-point source pollution. The need for master detention basins to supplement or replace individual detention basins or other facilities otherwise required at each site of development shall be considered. The need for expanded protection of environmentally critical areas including flood plains and wetlands shall be reviewed. Plans shall also be developed to address appropriate remedial storm water control measures. A survey of any institutional issues involved and of the social, environmental and economic implications of the proposed actions shall be included.

7:8-3.2 Flexibility of Approach

Each storm water management plan shall be cognizant of the unique character and limitation of the environment in the planning area. A main purpose is to distinguish those special conditions where an exception to the standards detailed in this document may be required to best manage storm water runoff. Unless circumstances justify exception or variance, the standards will be applicable to all development as specified in the remaining sections of this chapter.

7:8-3.3 Plan Conformity

(a) Each municipality shall coordinate storm water management plans and ordinance prepared under these regulations with soil and water conservation plans and regulations under the New Jersey Soil Conservation Act of 1937 as amended, N.J.S.A. 4:24-1 et seq., and with appropriate soil conservation districts. Storm water management plans shall refer to be in compliance with and not duplicate Soil Conservation District requirements for control of soil erosion. Additionally, such plans shall be coordinated with any storm water management plans prepared by the county and any other municipality in the basin, and in full compliance with the Water Quality Planning Act, N.J.S.A. 58:11A-1 et seq., and with any areawide plans for water quality relating to the river basins in the municipality. The storm water management plan and the storm water management ordinance or ordinances shall also be consistent with relevant Federal and State statutes, rules and regulations concerning storm water management, dam safety and flood control, and with the Water Supply Management Act, P.L. 1981, C.262, and the County Environmental Health Act, N.J.S.A 26:3A2-21 et seq.

7:8-3.4 General Standards

The following standards are specified for general use as minimums to be applied to major developments. Local plans and ordinances which require a greater degree of control or require retention for a greater period of time, or apply to classes of developments in addition to those specified herein, will be acceptable as long as the objectives are met. Plans and ordinances expressed in different terms but which are considered by the Department to achieve substantially the same objectives will also be acceptable.

(1) Flood and Erosion Control

The flood and erosion control standard for detention will require that volumes and rates be controlled so that after development the site will generate no greater peak runoff from the site than prior to development, for a 2-year, 10-year, and 100-year storm considered individually. These design storms shall be defined as either a 24-hour storm using the rainfall distribution recommended by the U.S. Soil Conservation Service when using U.S. Soil Conservation Service procedures (such as U.S. Soil Conservation Service, "Urban Hydrology for Small Watersheds," Technical Release No. 55,) or as the estimated maximum rainfall for the estimated time of concentration of runoff at the site when using a design method as the Modified Rational Method. Tabulations of estimated maximum rainfall are available from the Department. For purposes of computing runoff, all lands in the site shall be assumed, prior to development, to be in good condition (if the lands are pastures, lawns or parks), with good cover (if the lands are woods), or regardless of conditions existing at the time of with conservation treatment (if the land is cultivated), computation.

i. Any major agricultural development as defined in this chapter shall be submitted to the local Soil Conservation District for review and comment in accordance with this chapter and any Soil Conservation District guidelines. An agency may condition approval of such storm water control measures upon a positive recommendation of the appropriate Soil Conservation District.

(2) Water Quality Control

i. The water quality requirement for detention will require prolonged retention of a small design storm which shall be either a one (1) year frequency 24-hour storm using the rainfall distribution recommended for New Jersey by the U.S. Soil Conservation Service or a storm of one and one-quarter (1-1/4) inches of rainfall in two (2) hours. Provisions shall be made for it to be retained and released so as to evacuate ninety percent in approximately eighteen (18) hours in the case of residential developments and thirty-six (36) hours in the case of other developments. This is usually accomplished by a small outlet at the lowest level of detention storage, with a larger outlet or outlets above the level sufficient to control the small design storm. If the above requirement would result in a pipe smaller than three (3) inches in diameter, the period of retention shall be waived so that three (3) inches will be the minimum pipe size used.

ii. Where soils have sufficient permeability, the production of zero runoff from the site under conditions of the 1-1/4 inch water quality storm will be considered sufficient to meet the water quality requirement for residential developments, provided that the seasonal high groundwater does not rise to within two (2) feet of the bottom of the detention basin. For other than residential developments, approvals will be on a case-by-case basis after technical review by the designated authority. The object of this review will be to avoid pollution of groundwater. Other technology may be substituted pursuant to paragraph (a)4i, below.

(3) Detention Basins in Flood Plains

i. There will be no detention basins in the floodway except for those on-stream.

ii. New development, including construction of detention basins, should be avoided in flood plains, but where this is unavoidable, the plan and the ordinance must require a special examination to determine adequacy of proposed detention measures during the 100-year flood. One acceptable method is to apply the 100-year design storm to both the site and to the entire watershed contributing to the flood plain, assuming that the two peak simultaneously at the point in question. The time of concentration assumed for the entire watershed should be that appropriate to the larger area, rather than the shorter period applicable to the site.

iii. In addition such development must be in compliance with all applicable regulations under the Flood Hazard Area Control Act, N.J.S.A 58:16A-50 et seq.

iv. In default of an analysis such as described above, detention storage provided by construction of dikes or embankments below the elevation of the 100-year flood (either specially calculated or taken from an official flood plain delineation map) will be credited as effective storage at a reduced proportion as indicated in the table below:

TABLE 1

Allowable proportion of storage to be assumed usable in detention basins created by the construction of dikes and embankments of various sizes in drainage basins.

DRAINAGE BASIN AREA AT SITE

Elevation of storage provided below 100-year flood level	Less than 5 Sq. Mi.	5-100 Sq. Mi.	Over 100 Sq. Mi.
Less than 2 ft.	40 %	65 %	90 %
2 - 4 ft.	25 %	50 %	75 %
Over 4 ft.	10 %	25 %	50 %

v. This effective detention storage plus any other supplementary measures, will be required to provide for storm water detention, in accordance with establish standards. However, the gross storage considered for this evaluation will not exceed that which would be filled by runoff of a 100-year storm at the site.

vi. In making computations the volume of not fill added to the flood hazard area portion of the project site will be subtracted from the capacity of effective detention storage provided. Net fill is defined as the total amount of fill created by the project less the amount of material excavated during the construction of the project, both measured below the elevation of the 100-year flood but above the elevation of low water in the stream. There fore, net storage provided by excavation in the flood plain above the seasonal high water table will be credited 100% towards effective detention storage.

(4) Alternatives to Detention Basins

i. It is not necessary that basic requirements for water quantity and quality control be satisfied by means of detention basins. Measures including but not limited to rooftop storage, tanks, infiltration, pits, porous pavement, dry wells, gravel layers underneath paving, or sheet flow through vegetated areas may be used for the purpose, with appropriate consideration for length of life and feasibility of continued maintenance in accordance with technical guidance from the Department. Vacuum street sweeping may be substituted for the water quality requirement, in cases in which continuity of the service can be assured, and where the pollution in question originates on the pavement.

ii. Non-structural management practices, including but not limited to cluster land use development, open space acquisition, stream encroachment and flood hazard controls, protection of wetlands, steep slopes and vegetation should be coordinated with detention requirements. Changes in land use can often reduce the scope and cost of detention provisions required by means of appropriate changes in runoff coefficients.

iii. Municipalities should consider waiving or amending local requirements for extensive impervious pavement, curbing and storm sewers where small pavement areas could be used or where grassed swales could be substituted.

(5) Maintenance and Repair

i. Maintenance of detention basins and infiltration means, or of other alternatives, is a very important aspect of a storm water management program. Control measures shall be designed so as to provide for mechanical maintenance operations. Responsibility for operation and maintenance of storm water management of storm water management facilities, including periodic removal and disposal of accumulated particulate material and debris, unless assumed by a governmental agency, shall remain with the property owner and shall pass to any successor or owner. In the case of developments where lots are to be sold, permanent arrangements, satisfactory to the approving agency shall be made to insure continued performance of these obligations.

ii. A schedule of maintenance inspections shall be incorporated into the local ordinance. Ordinances shall also provide that in cases where maintenance or repair is neglected, the municipality or the county has the authority to perform the work and to back-charge the owner.

(6) Control Measures

Ordinances and plans shall be designed to allow for flexibility in the development of control measures. In Phase II planning, the use of regional basin or watershed systems and the consideration of economies of scale shall be investigated wherever practical. In addition, the economic advantage of non-structural measures (i.e. changes in land use, densities, site configuration, and use of natural topography) should be considered. Combinations of remedial measures for existing systems and preventative measures for new developments shall be investigated.

(7) Propagation of insects

Municipal plans should be prepared so as to minimize propagation of insects, particularly mosquitos.

(8) Aestetics

Detention facilities should be designed in a harmonious and attractive manner.

7:8-3.5 Variance or Exemption From the Standards

If a municipality grants a variance or exemption from the standards set forth in their storm water management plan and control ordinance, a written report shall be made to the county detailing the nature of the variance, the change(s) requested, and an explanation of the decision. An exemption from the county ordinance or regulations or resolution shall be reported in the same fashion to the Administrator, Water Supply and Watershed Management Administration, Division of Water Resources, Department of Environmental Protection.

7:8-3.6 Stormwater Control Ordinance

The storm water control ordinance is required to be adopted by the municipality within one year of the completion of a storm water management plan funded pursuant to Section 6 of this Act. It is an implementation document for the plan. The ordinance shall conform with all requirements of this chapter. Upon adoption of this chapter, the Department will supply each municipality with a Model Storm Water Control Ordinance as a guide for municipalities to prepare their own ordinances.

Appendix B

A Draft Stormwater Management Ordinance for Municipalities

Division of Water Resources

New Jersey Department of Environmental Protection

This ordinance has been prepared by the New Jersey Department of Environmental Protection, Division of Water Resources as a guide for participants in the State's Storm Water Management Program. In particular, this ordinance is designed to comply with requirements of N.J.A.C. 7:8-3.1(a) 1. The intent of the ordinance is to provide preventive measures to be applied to the site plan review process. The general standards of this ordinance, Section V, shall be considered as minimums and any municipal ordinance, providing equal or greater protection as defined by N.J.A.C. 7:8-2.1, and which are considered by the Department to achieve substantially the same objectives will be acceptable.

It should be noted that this ordinance is designed for general application, and may be modified. Prior to adoption, however, any modified ordinance must be reviewed and approved by the appropriate County agency as required by 7:8-2.3 or by the State's Bureau of Flood Plain Management.

STORMWATER MANAGEMENT ORDINANCE

AN ORDINANCE ESTABLISHING REQUIREMENTS FOR THE MANAGEMENT OF STORMWATER WITHIN THE ____________________ OF ____________________ AND THE STATE OF NEW JERSEY.

SECTION 1. SHORT TITLE

This ordinance shall be known and may be cited as "The Stormwater Management Ordinance" of the of ______________________________ of ________________________.

SECTION II. STATEMENT OF PURPOSE

It is hereby determined that the lakes and waterways within the ____________________ of ____________________ are at times subjected to flooding; that such flooding is a danger to the lives and property of the public; that such flooding is also a danger to the natural resources of the ____________________ of ____________________, county and State; that development tends to accentuate such flooding by increasing stormwater runoff, due to alteration of the hydrologic response of the watershed in changing from the undeveloped to the developed condition; that such increased flooding produced by the development of real property contributes increased quantities of water-borne pollutants, and tends to increase channel erosion; that such increased flooding, increased erosion, and increased pollution constitutes deterioration of the water resources of the ____________________ of ______________________, the county and the State; and that such increased flooding, increased erosion and increased pollution can be controlled to some extent by the regulation of stormwater runoff from such development. It is therefore determined that it is in the public interest to regulate the development of real property and to establish standards to regulate the additional discharge of stormwater runoff from such developments as provided in this ordinance.

SECTION III. APPLICABILITY

The provisions of this ordinance shall be applicable to each of the types of development named below.

1. All site plans and subdivision plans that will add one or more acres of impervious surface (except as provided in subparagraph 3 below).

2. Any construction of one or more of the following uses: (a) confined feeding and holding areas that provide for more than 100 head of cattle, 15,000 head of poultry, 500 swine, 4,000 turkeys or 10,000 ducks; this section shall also apply to all other equivalent numbers of animal units as determined by the SCS procedure for measuring BOD producing potential. (b) pipelines, storage, or distribution systems for petroleum products or chemicals; (c) storage, distribution or treatment facilities (excluding onsite sewage disposal systems) for liquid waste; (d) solid waste storage, disposition, incineration or landfill; (e) quarries, mines or borrow pits; (f) land application of sludge or effluents; and (g) storage, distribution or treatment facilities for radioactive wastes. Except where permitted and subject to a New Jersey Pollutant Discharge Elimination System (NJPDES) permit or a approved DPCC Plan.

3. In the event that control of storm water runoff is mandated in certain areas for construction covering less than one acre of ground, such lesser developments shall come under provisions of this ordinance.

SECTION IV. PROCEDURE (Recommended)

A. Burden of Proof

Whenever an applicant seeks a municipal approval of a development to which this ordinance is applicable from any board or official of the municipality, that applicant shall be required to demonstrate that his project meets the standards set forth in this ordinance.

B. Submission Materials Due

The applicant shall submit materials, as required by Section VI hereof, to the municipal board or official from which he seeks municipal approval prior to or at the same time he submits his application for the municipal approval.

C. Review

The applicant's project shall be reviewed by the municipal board or official from which he seeks his municipal approval. That municipal board or official shall consult with the municipal engineer to determine if the project meets the standards set forth in this ordinance.

D. Time for Decision

The municipal board or official shall promptly determine if the project meets the standards set forth in this ordinance. The time for that determination should be the time permitted to review and act on the applicant's application for a municipal approval.

E. Failure to Comply

Failure of the applicant to demonstrate that the project meets the standards set forth in this ordinance is reason to deny the applicant's underlying application for a municipal approval.

F. Variance

For good reason, the municipality may grant a waiver of the standards given in section V below. In each such case, the municipality must make a report within 30 days to the county planning board, giving a full explanation of the nature of the variance, and the reasons why it was granted.

SECTION V. STANDARDS

Each proposed project not exempted from the operation of this ordinance shall meet the following storm drainage standards:

A. General Standards

The project plans submitted shall demonstrate careful consideration of the general and specific concerns, values and standards of the municipal Master Plan and applicable county, regional and state storm drainage control programs, any County Mosquito Commission control standards and shall be based on environmentally sound site planning, engineering and architectural techniques.

B. Alternatives to Detention Basins

1. It is not necessary that basic requirements be satisfied by means of detention basins. Rooftop storage, tanks, infiltration pits, dry wells, or gravel layers underneath paving, may be used for the purpose, with appropriate consideration for length of life and feasibility of continued maintenance.

2. Non-structural management practices, such as cluster land use development, open space acquisition, stream encroachment and flood hazard controls should be coordinated with detention requirements. Changes in land use can often reduce the scope and cost of detention provisions required by means of appropriate changes in runoff coefficients.

C. Specific Standards

(a) Flood and Erosion Control -

A detention facility must accommodate site runoff generated from 2 year, 10 year and 100 year 24 hour storms considered individually (in each case a type III rainfall as defined in Soil Conservation Service Publications). Runoff greater than that occurring from the 100 year 24 hour storm will be passed over an emergency spillway. Detention will be provided such that after development neither the peak rate of flow from the site, nor the total flow during the hour of maximum releases will exceed the corresponding flows which would have been created by similar storms prior to development. For purposes of computing runoff, all lands in the site shall be assumed, prior to development, to be in good condition (if the lands are pastures, lawns or parks), with good cover (if the lands are woods), or with conservation treatment (if the land is cultivated), regardless of conditions existing at the time of computation.

(b) Water Quality Control

In order to enhance water quality of storm water runoff, all storm water management plans must provide for the control of a water quality design storm. The water quality design storm shall be defined as the one year frequency SCS Type III 24 hour storm or a 1-1/4 inch two hour rainfall.

The water quality design storm shall be controlled by one of the following practices.

1. In "dry" detention basins, provisions shall be made to insure that the runoff from the water quality design storm is retained such that not more than 90% will be evacuated prior to 36 hours for all non-residential projects or 18 hours for all residential projects. The retention time shall be considered a brim-drawdown time, and therefore shall begin at the time of peak storage. The retention time shall be reduced in any case which would require an outlet size diameter of 3" or less. Therefore, 3" diameter orifices shall be the minimum allowed.

2. In permanent ponds or "wet" basins, the water quality requirements of this ordinance shall be satisfied where the volume of permanent water is at least three times the volume of runoff produced by the water quality design storm.

3. Infiltration practices such as dry wells, infiltration basins, infiltration trenches, buffer strips, etc., may be used to satisfy this requirement provided they produce zero runoff from the water quality design storm and allow for complete infiltration within 72 hours.

{Note: Any municipality that wishes to allow for water quality control techniques in addition to those described above shall submit evidence of the effectiveness of the control technique to the Department for review and approval prior to adoption of the ordinance.}

(c) In all cases, multiple level outlets or other fully automatic outlets shall be designed so that discharge rates from the development for the design storms will not be increased from what would occur if the development were not constructed. Outlet waters shall be discharged from the development at such locations and velocities as not to cause additional erosion or cause additional channels downstream of the development.

(d) Where the project consist of two phases, (a) new construction which requires provisions of storm drainage under the terms of this ordinance and (b) repair or rehabilitation of structures and surfaces which does not result in increasing the extent of impervious areas or in rendering existing surfaces less pervious, the detention requirements may be computed on the basis of phase (a) exclusively.

(e) If detention basins or other detention facilities are provided through which water passes at times other than following rainfall, the municipal engineer should be consulted concerning design criteria. It will be necessary for detention requirements to be met, despite the necessity of passing certain low flows. This applies to all on stream or on line detention basins.

(f) Outlets from detention facilities shall be designed to function without manual, electric, or mechanical controls.

(g) The retention of site runoff as required by this ordinance will result in the accumulation in the detention basin of sediment, including particulate polluting substances, silt, and debris. Provision must be made for periodic removal of accumulated solid materials. Computations for storage capacity shall include estimates for one year's accumulation of solid materials.

(h) Dams - Any stormwater basin that impounds water through the use of an artificial dike, levee or other barrier and raises the water level five feet or more above the usual, mean low water height when measured from the downstream toe-of-dam to the emergency spillway crest is classified as a dam and subject to N.J.A.C. 7:20 the New Jersey Dam Safety Standards. All such dams must be designed, constructed, operated and maintained in compliance with the rules of N.J.A.C. 7:20.

(i) In many instances, the provisions of separate detention facilities for a number of single sites may be more expensive and more difficult to maintain than provisions of joint facilities for a number of sites. In such cases, the municipality will be willing to consider provisions of joint detention facilities which will fulfill the requirements of this regulation. In such cases, a properly-planned staged program of detention facilities may be approved by the municipality in which compliance with some requirements may be postponed at early stages while preliminary phases are being undertaken and construction funds accumulated. The necessary planning to facilitate such arrangements may be accomplished by Phase II planning under provisions of N.J.A.C. 7:8.

D. Regional Storm Water Planning Areas

All proposed projects located in a designated regional planning area will be required to comply with the provisions of this section.

(a) The proposed project shall include adequate onsite storm water management controls to satisfy the requirements of section C (b) - Water Quality Control and must accomodate the site runoff generated from the 2-year 24 hour storm such that the maximum rate of runoff will not increase as a result of the proposed developments.

(b) In lieu of providing onsite control of the 10-year and 100-year storms, the proposed project shall contribute the required fee towards the implementation the proposed regional storm water control facilities. Such fee shall be based on the increased volume of runoff resulting from the proposed development under conditions of the 100-year 24 your Soil Conservation Service Type III storm. The increased runoff shall be determined by the Soil Conservation Service runoff curve number procedure utilizing the appropriate curve numbers from Table A. The fee shall equal $_____ per acre foot of increased runoff volume.

(For example, if the predeveloped runoff volume produced by the 100-year storm was determined as 1.0 acre foot and the developed runoff volume was determined as 3.0 acre feet, the fee will be based on the change in volume, or 2.0 acre feet.)

The fee shall be paid to the designated regional storm water planning group upon final planning board approval of the proposed project.

E. Detention Facilities in Flood Hazard Areas

1. Whenever practicable, developments and their stormwater detention facilities should be beyond the extent of the flood hazard area of a stream. When that is not possible and detention facilities are proposed to be located partially or wholly within the flood hazard area (as defined by the New Jersey Division of Water Resources, Bureau of Flood Plain Management), or other areas which are frequently flooded, some storm conditions will make the facility ineffective at providing retention of site runoff. This will happen if the stream is already overflowing its banks and the detention basin, causing the basin to be filled prior to the time it is needed. In such cases the standards established in these regulations will be modified in order to give only partial credit to detention capacities located within a flood hazard area. The credit will vary in a ratio intended to reflect the probability that storage in a detention basin will be available at the time a storm occurs at the site.

2. Detention storage provided below the elevation of the edge of the 100 year flood plain will be credited as effective storage at a reduced proportion as indicated in the table below:

TABLE A

Runoff Curve Numbers for Selected Land Use Descriptions

	Hydrologic Soil Groups			
Industrial/Commercial or Residential Categories	A	B	C	D
10% Impervious 90% lawns in good condition	45	65	76	82
20% " 80% " " " "	51	68	79	84
30% " 70% " " " "	57	72	81	85
40% " 60% " " " "	63	76	84	87
50% " 50% " " " "	69	80	86	89
60% " 40% " " " "	74	83	88	91
70% " 30% " " " "	80	87	91	93
80% " 20% " " " "	86	91	93	94
90% " 10% " " " "	92	94	96	96
10% " 90% woodland in good condition	32	59	73	79
20% " 80% " " " "	40	64	76	81
30% " 70% " " " "	47	68	78	83
40% " 60% " " " "	54	72	81	85
50% " 50% " " " "	62	77	84	88
60% " 40% " " " "	69	81	87	90
70% " 30% " " " "	76	85	90	92
80% " 20% " " " "	83	89	92	94
90% " 10% " " " "	91	94	95	96

To obtain CN values for other percentages use an arithmetic interpolation.

Size of Drainage Area*

Elevation	Less than Sq. Mi.	5-100 Sq. Mi.	Greater than 100 Sq. Mi.
Less than 2' below	40%	65%	90%
Between 2' and 4' below	25%	50%	75%
Over 4' below	10%	25%	50%

* Area contributing floodwaters to the flood hazard area at the site in question.

This effective detention storage will be required to provide for drainage of the developed land in accordance with the criteria already established in these regulations. However, the gross storage considered for crediting will not exceed that which would be filled by runoff of a 100 year storm from the site.

3. As an alternative to approach 2 above, if the developer can demonstrate that the detention provided would be effective, during runoff from the 100 year 24 hour Type III storm, peaking simultaneously at the site and on the flood hazard area, his plan will be accepted as complying with provisions of paragraph 2 above.

4. In making computations under paragraph 2 or 3 above, the volume of net fill added to the flood hazard area portion of the project's site will be subtracted from the capacity of effective detention storage provided. (Net fill is defined as the total amount of fill created incidental to the completion of the project less the amount of excavated material removed during the completion of the project, both measured below the elevation of the edge of the flood hazard area.)

5. Where detention basins are proposed to be located in areas which are frequently flooded but have not been mapped as flood hazard areas, the provisions of either paragraph 2 or 3 will be applied, utilizing the elevation of a computed 100 year flood.

6. Developers are also required to show compliance with the Flood Hazard Areas regulations of the Department of Environmental Protection.

F. Standards for Stream Corridor Protection (Recommended)

To the extent practicable and consistent with other site planning criteria, and with appropriate beneficial use of the site as a whole, it is recommended that no alteration of the natural terrain should occur and no impervious surfaces should be located, within a stream corridor. The corridor should include all flood plain areas, adjacent slopes of 12% or greater, and contiguous areas where the depth of the seasonal high water table is one foot or less.

SECTION VI. SUBMISSIONS (Recommended)

The following submissions shall be required for each proposed project subject to review under this ordinance. The applicant is free to combine exhibits or otherwise consolidate the required information, so long as all required information is clearly presented.

A. Topographic Base Map

Topographic base map of the site, and extending a minimum of 200' beyond the limits of the proposed development at a scale of 1" = 200' or greater, showing 2' contour intervals. The map shall indicate at least the following: existing surface water drainage, marshlands, outlines of woodland cover, existing man-made structures, roads, utilities, bearing and distances of property lines, and significant natural and man-made features not otherwise shown.

B. Vicinity Map

Applicants must prepare a map at a scale of 1" = 400' or greater on a paper print of the latest air photographs available, updated in the field to reflect current conditions, showing the relationship of the proposed development to significant features in the general surroundings. The map must indicate at least the following: roads, pedestrian ways, access to the site, adjacent land uses, existing open space, public facilities, landmarks, places of architectural and historic significance, utilities, drainage (including, specifically, streams and other surface water shown on U.S.G.S. and soils maps), and other significant features not otherwise shown.

C. Environmental Site Analysis

A written and graphic description of the natural and man-made features of the site and its environs. This description should include a discussion of soil conditions, slopes, wetlands, vegetation and animal life on the site. Particular attention should be given to unique, unusual, or environmentally sensitive features and to those that provide particular opportunities or constraints for development.

D. Project Description and Site Plan(s)

A map (or maps) at the scale of the topographical base map indicating the location of proposed buildings, roads, parking areas, utilities, structural facilities for detaining or recharging stormwater and sediment control, and other permanent structures. The map(s) shall also clearly show areas where alterations in the natural terrain, cover, and grade are proposed, and changes in natural cover, including lawns and other landscaping. A written description of the site plan and justification of proposed changes in natural conditions may also be provided.

E. Water Detention Facilities Map

The following information, illustrated on a map of the same scale as the topographic base map, shall be included:

(a) Total area to be paved or built upon, estimated land area to be occupied by water detention facilities and the type of vegetation thereon, and details of the proposed plan to control and dispose of surface water.

(b) Details of all water detention plans, during and after construction, including discharge provisions, discharge capacity for each outlet at different levels of detention and emergency spillway provisions with maximum discharge capacity of each spillway.

(c) Maximum discharge and total volume of runoff which would occur from the project area before and after development for the following storms:

(1) One and a quarter inch of rainfall occurring within two hours, or a one year frequency Type III 24 hour storm.

(2) The specified design storms. (2 year, 10 year, and 100 year 24 hour SCS Type III.)

The municipal official or board reviewing an application under this ordinance may, in consultation with the municipal engineer, waive submission of any of the above requirements when the information requested is impossible to obtain or when it would create a hardship on the applicant to obtain and where its absence will not materially affect the review process.

SECTION VII. MAINTENANCE AND REPAIR

Responsibility for operation and maintenance of detention facilities, including periodic removal and disposal of accumulated particulate material and debris, shall remain with the owner or owners of the property with permanent arrangements that it shall pass to any successive owner, unless assumed by a government agency. If portions of the land are to be sold, legally binding arrangements shall be made to pass the basic responsibility to successors in title. These arrangements shall designate for each project the property owner, governmental agency, or other legally established entity to be permanently responsible for maintenance, hereinafter in this section referred to as the responsible person.

Prior to granting approval to any project subject to review under this ordinance, the applicant shall enter into an agreement with the municipality to ensure the continued operation and maintenance of the detention facility. This agreement shall be in a form satisfactory to the municipal attorney, and may include, but may not necessarily be limited to, personal guarantees, deed restrictions, covenants, and bonds. In cases where property is subdivided and sold separately, a homeowner's association or similar permanent entity should be established as the responsible entity, absent an agreement by a governmental agency to assume responsibility.

In the event that the detention facility becomes a danger to public safety or public health, or if it is in need of maintenance, the municipality shall so notify in writing the responsible person. From that notice, the responsible person shall have fourteen (14) days to affect such maintenance and repair of the facility in a manner that is approved by the municipal engineer or his designee. If the responsible person fails or refuses to perform such maintenance and repair, the municipality may immediately proceed to do so and shall bill the cost thereof to the responsible person.

SECTION IX. FEES (Recommended)

In addition to any fee due to the municipality as a result of the applicant's underlying application for a municipal approval, there shall be due to the municipality at the time of submission of materials in support of this application a fee as follows:

(a) for each 10,000 square feet to be graded or developed as part of the project.

(b) This fee is an approximation of the estimated cost to the municipality to have its professional staff and consultants review the proposed project.

SECTION X. SEVERABILITY

Should any section or provision of this ordinance be declared invalid by a court of competent jurisdiction, such a declaration shall not affect the remaining sections or provisions of this ordinance which are hereby declared to be severable.

SECTION XI. EFFECTIVE DATE

This ordinance shall take effect upon final passage and approval by the county planning agency or water resources association as appropriate or sixty (60) days after submission to said agency if they fail to act.